

ECOLOGICAL SURVEYS OF CORAL REEFS

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WITH TWO TEXT-FIGURES AND SIXTEEN PLATES.

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I. A QUANTITATIVE ECOLOGICAL STUDY OF TRAVERSES ACROSS LOW ISLES REEF

INTRODUCTION.

By T. A. STEPHENSON,

Professor of Zoology in the University of Cape Town.

WHEN planning the ecological work which was to be carried out at Low Isles, I had in mind two lines of investigation connected with the estimation of the populations of the reef. The first was to make a general survey of the whole area in order to determine the broad outlines of the distribution of organisms, and their relation to the several available habitats and to the conditions prevailing therein. The result of this survey has already been published in this volume (Vol. III, No. 2). The second objective was to make quantitative surveys of a number of selected strips or patches of the reef, so that the general survey might be illustrated by accurate examples showing exactly and in detail how the organisms were arranged in some of the typical habitats. Originally we hoped to survey patches of sand and mud (sifting out and counting their inhabitants), as well as regions where the substratum is mainly rocky; but shortage of time put an end to this possibility, and permitted us only to survey the surface-life along two narrow strips of the reef.

The two traverses studied both lie on the leeward side of the reef. It would have been very instructive to compare a section down the windward slope with another across the leeward slope; but in practice this was impossible, because the weather conditions at the windward side are normally too windy to permit one to work there, and it could only be done by choosing days here and there over a longer period than was available to us.

The two sections worked were chosen for the following reasons: Traverse I illustrates very well the contrast between the growth of corals and algae which can exist under the somewhat stringent conditions prevailing in a moat (see Vol. III, No. 2, p. 45), and that which is to be found on a slope open to the sea at all states of the tide; it also includes areas of the reef-flat and boulder-tract. Traverse II (leaving out of account the small areas of beach-sandstone and moat which it first crosses) is approximately comparable to the seaward-slope portion of Traverse I, but with modifications, since it is divided rather sharply into a slightly higher landward part and a lower seaward portion, terminating ultimately at a depth of $5\frac{1}{2}$ feet below datum. The landward part crosses and corresponds

to the region of Luana Reef marked A1 on the key chart of Low Isles published in Vol. III, No. 2, Text-fig. 2; the seaward part crosses and corresponds to the area A2. The landward portion uncovers at any tide which falls to a level 0·8 feet above datum; the seaward part is submerged at such a tide, but at the lowest springs (the extreme recorded being 0·4 feet below datum) its highest parts are exposed; its deeper regions are therefore always submerged. The region A1, therefore, as a result of its level, is exposed or awash more frequently and for longer periods than the area A2, though submerged at neap tides. The fall in level from A1 to the beginning of A2, although so slight, is reflected in the coral fauna, the response to the improved conditions being immediately apparent, and being maintained, of course, to the end of the traverse, as the level continues to fall. This improvement of the fauna at a critical level is one of the most interesting points illustrated by the traverse. (See also Vol. III, No. 2, p. 62, and Pl. XIV.)

Both traverses have the advantage of crossing regions in which observations on the periodic physical and chemical changes in the environment were made by A. P. Orr. In order to make the data available as complete as possible, level-sections along both traverses were taken by M. A. Spender. Nothing is more evident in modern ecological work than the necessity for correlating details connected with the arrangement of organisms with accurate determinations of level, more especially in the intertidal zone, where slight changes of level involve important modifications in the range of exposure to which organisms are subjected.

It will be noticed that most of the data which follow refer to corals and algae only. A more comprehensive survey in the time available was impossible. The omission is in fact less considerable than might at first appear, since the corals and algae are undoubtedly the dominant organisms in the areas studied. The work must therefore be regarded as a survey of the *principal sedentary oxygen-producing organisms in areas of mainly rocky substratum*. (The production of surplus oxygen takes place, of course, only during daylight.)

The work was started by several of us in the survey of a patch on Batt Reef, in 1928. This taught us the proper method both of making the counts and of representing the result graphically in the way adopted for the plates illustrating this paper. Later on I chose two suitable traverses at Low Isles, and when Dr. Fraser and Dr. Manton joined the expedition, I asked them if they would take over the detailed survey of these. This paper is the outcome of their work. The counting of organisms was carried out jointly by Dr. Fraser and Dr. Manton; but Dr. Manton is solely responsible for drawing up the following report. We are indebted to Miss K. Cole for assistance in the redrawing of the coral maps for the plates.

The algae collected in connection with this work have been determined by G. Tandy. For the names of the corals Prof. Matthai* and I share the responsibility. I have worked carefully through a series of dried specimens in order to check the conclusions as to the identity of the species which were made in the field, and to correlate our determinations with those of Prof. Matthai. A set of specimens held by us to be typical of the species here mentioned will be deposited in the British Museum (Natural History).

* [It is to be regretted that Prof. Matthai, after supplying the names used in this report, found himself unable to complete the systematic examination of the corals. It is hoped to publish later a systematic report on the group by another hand, but any divergences from the nomenclature adopted here will be specially noted.—W. T. CALMAN.]

PREVIOUS WORK.

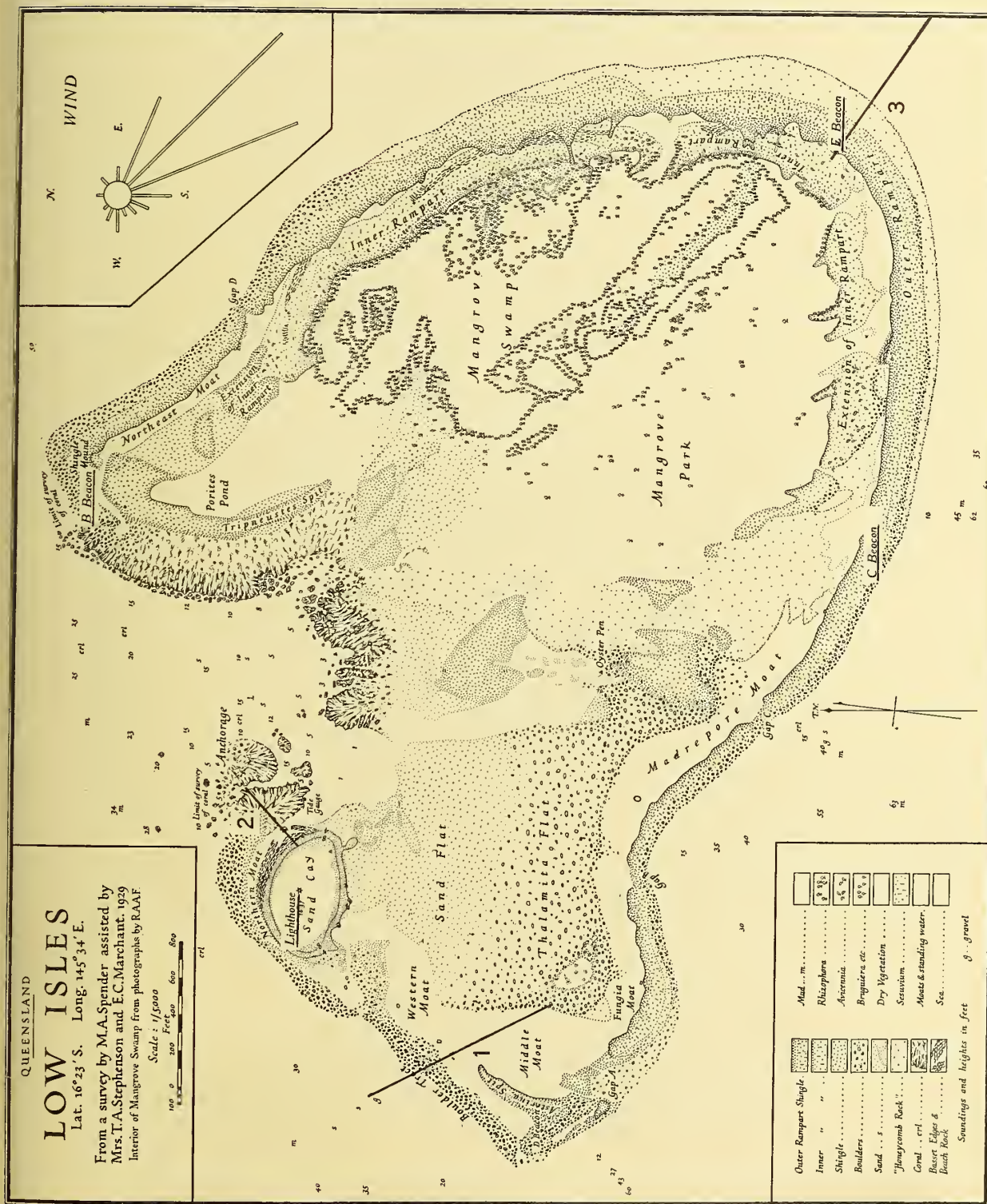
The more important existing records of detailed examinations carried out on restricted areas of coral reefs are those by Mayor (1918 and 1924) on the fringing reefs of Maer Island, near the northern end of the Great Barrier Reef, and Tutuila, in Samoa, that by Baker (1925) on a fringing reef in the New Hebrides, and the short account by Hedley and Taylor (1907) of a traverse across East Hope Isle within the Great Barrier Reef. The three fringing reefs have land of some height behind them, and present an entirely different structure from that of Low Isles Reef, besides differing somewhat from one another. Thus features of interest brought out by the examination of these reefs cannot be compared directly with conditions on Low Isles. East Hope Isle, like Low Isles, is an "island reef", but the traverse across the former records only the outstanding forms growing on the various parts, and levels were not determined.

Of the traverses across fringing reefs, that across a New Hebrides fringing reef, half a mile in width, records the approximate abundance and zoning of the dominant corals across the reef-flat, coral growth being most abundant near the shore where *Montipora ramosa* and *Goniopora* are dominant. A barren "boulder zone" lies near the seaward edge, and the survey was not continued down the outer slope. The Maer Island fringing reef on the weather side of the island bears a "lithothamnion ridge" on its seaward edge 1800 feet from the shore; while the Aua reef, Tutuila, is bounded seawards at 855 feet from the shore by a rich acropore zone. The reef flats of both are somewhat similar. The numbers of corals occurring on a 50-foot-wide strip at Maer Island and on a 24-foot-wide strip at Tutuila were recorded. Both show a maximum coral growth some distance behind the edge of the reef in relatively quiet water, where the surge dies out, but the maximum variety of corals is found close behind the edge. A zoning of corals is present, but 90% of the colonies consist of four genera—*Porites*, *Acropora*, *Pocillopora* and *Seriatopora*—with *Psammocora* replacing *Seriatopora* on the Aua reef, Tutuila. The main factors concerning the distribution of corals were considered to be temperature, silt, the mechanical effects of moving water and a struggle between species. The algae were few and were not considered quantitatively.

POSITIONS OF SURVEYS ON LOW ISLES AND METHODS EMPLOYED.

On Low Isles a survey was made along Traverse I, shown on the map in Text-fig. 1, lying across the leeward side of the reef. The traverse extends from the outer edge of the Thalamita Flat across the edge of the reef and down its seaward slope until coral growth ceases and the muddy sea bottom is reached. The richest coral-bearing areas of the reef, those of the Moat and of the Seaward Slope, are thus encountered, besides the more barren reef flat and Boulder Tract. It was possible to complete the survey down the seaward edge of the reef to the lower limit of coral growth owing to the small depth at which the muddy sea floor is encountered on the leeward side.

A second survey was made along Traverse II (see Text-fig. 1) from the beach of the sand cay across the end of the Northern Moat, and passing over the reef to terminate on a barren sandy stretch.



TEXT-FIG. 1.—Low Isles, from Spender's survey, showing the positions of the Traverses which were surveyed in detail. Traverse I passes from the Thalmita Flat across the Moat and Boulder Tract, and Traverse II passes from the Beach of the sand cay across the reef towards the Anchorage. Part of the area enclosed by a ring in the Madrepore Moat is shown in the large-scale map on Plate X, and part of the Western Moat crossed by the Traverse is shown in Plate I. Traverse III passes through E beacon in line with the lighthouse and traverses the seaward edge of the reef.

A strip of reef one yard in width was examined along each of the traverses. Measurements of levels and distances were carried out by M. A. Spender. Positions and distances along the traverses are given in feet from the beginning of each traverse, and levels are given in feet above or below datum level.* Each traverse was marked out by a series of stakes driven into the reef, a cord being stretched between them. Measurements along the ground were taken with a steel tape, the probable error of the methods employed not exceeding 1/10 foot per 100 feet. Levels were determined with a Watts-Zeiss reversible level, the readings being taken to the nearest 1/100 foot. The probable error does not exceed 0.03 foot per mile. A rectangular wooden frame 1 × 2 yards and cross-partitioned into square feet was placed successively along the traverse, and all the corals and algae occurring on every square yard of reef were recorded. Counts of species occurring on each square yard were made as far as possible, but extensive colonies were recorded in terms of the size of the area covered. Only the presence or absence of many of the smaller algae was noted, and an approximate estimation of their relative abundance per square yard was made. All exposed surfaces were examined, and as far as possible the crevices and hollows in the rocks, but large slabs of rock were not lifted.

On the Seaward Slopes of the reef measurements were made with the steel tape, so far as possible along the contour of the ground. The methods we used permitted an error of about 2 feet per 100 feet, and deeper than 10 feet the readings are likely to be in error by ± 1 foot. In water deeper than about 4 feet measurements were made by sounding. The survey from about 3 feet below datum onwards was carried out by means of a diving helmet. The line of the traverse below the water was maintained by dropping a rope, with an anchor at each end, so that it lay in line with the stakes marking the traverse across the reef flat. As the bottom was very uneven, short lengths were used between the anchors, and the line was carried successively seawards. The wooden frame was suitably weighted so that it would sink easily, and the record of the survey of each square yard was made in pencil on sheets of white ground-glass. Ground-glass was found to be far more serviceable than slates for use under water, as the pencil marks do not rub off easily. The width of the traverse is admittedly narrow, but owing to the difficulties of manipulating a large frame single-handed under water, and to the limited time available, no greater width could be attempted.

A third survey was made along Traverse III (Text-fig. 1) across the S.E. windward edge of the reef. Owing to lack of available time and suitable weather conditions this survey was not quantitative, and was much less detailed than the other two. However, it serves to contrast the seaward slopes on the leeward and windward sides of the reef, and may be compared with the windward edge of the Outer Barrier Reefs.

Finally large-scale maps of small portions of the traverses were made with the help of the wooden grid frame used for counting the organisms on the traverses. Small areas up to 20 square yards were also mapped in the Madrepore Moat, in the Anchorage and on the vertical face of a coral patch, so that ready comparisons of these different coral-bearing regions could be made.

* Datum level is that of low water springs as determined by H.M.S. "Penguin" in 1905, and lies at 17 feet 2 inches below the top of the lighthouse steps.

THE SURVEY OF TRAVERSE I.

The position of this traverse is seen in Text-fig. 1, and a level section along it together with sea-levels are given with the graphs showing the distribution of organisms (Plate I). In Text-fig. 2, *a*, a section is shown passing seawards beyond the end of the traverse. The vertical and horizontal scales are here equal. The reef here is covered at high-water springs by about 7 feet of water. From the edge of the Thalamita Flat the traverse passes through the deeper parts of the Western Moat, over the Boulder Tract, and down the outer slope to the muddy sea bottom at a depth of about 20 feet below datum. Thereafter an even, gentle slope descends to 37 feet below datum at about 1600 feet from the beginning of the traverse (see Text-fig. 2, *a*). The Boulder Tract forms the highest part of the traverse, and at low spring tides is dry between 703 and 826 feet. On its seaward side the water level alters directly with the state of the tide. Within the Boulder Tract, on the other hand, water becomes held up, so leaving the Moat flooded and shallow pools of water standing on the flat, while the water ebbs to a lower level outside. Water remains held up in the Moat for a maximum period of $5\frac{1}{2}$ hours, and lies at a minimum of 2.7 feet above datum (see level section).

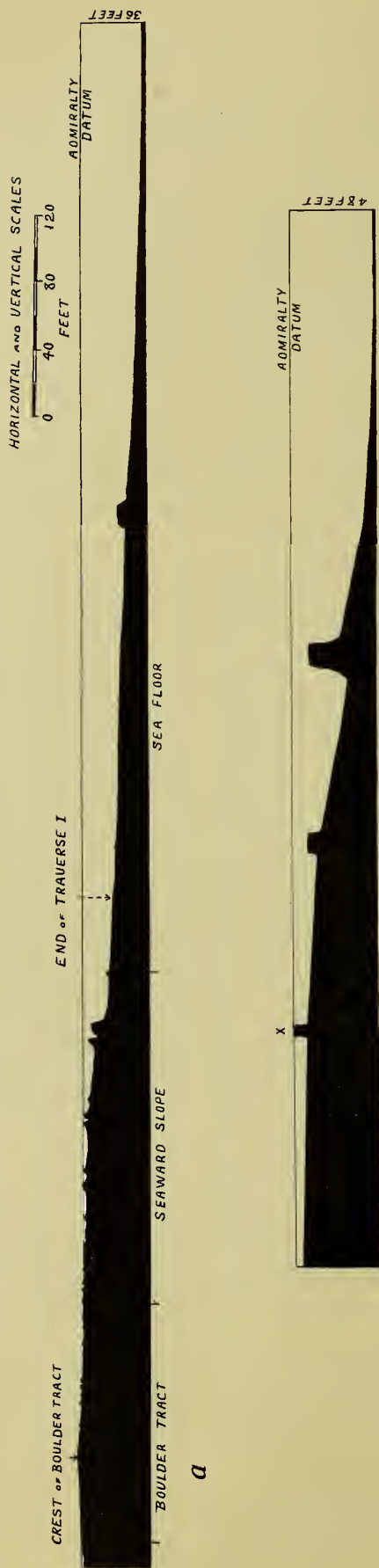
The traverse may conveniently be divided into the following portions for subsequent consideration: (1) The *Reef Flat*, 0–25 feet, is left dry at low water, and lies at about 2.8 feet above datum. The traverse then merges into (2) *The Moat*. The shallower part of the moat extends to 250 feet, and has an uneven bottom at about 2.4 feet above datum. The deeper part of the moat follows, with the bottom at a minimum of 1.8 feet above datum and extends to 700 feet; its floor is uneven, and the deepest parts lie near the Boulder Tract between 515 and 640 feet. (3) The *Boulder Tract* emerges by a gentle slope from the Moat, not by a precipitous scarp as found at the junction of the rampart (Spender, 1930, p. 197) and the other moats. From its crest it slopes downward to 846 feet at about 1 in 25, but the surface is interrupted by projecting boulders. Beyond lies (4) the *Seaward Slope*, a permanently submerged region of large boulders, coral heads and luxuriantly growing coral extending to 1045 feet. The reef profile from the crest of the boulder tract is convex up to 1014 feet, and the downward slope gradually steepens to about 1 in 14. A steeper slope next descends to 1045 feet, dropping steeply at first and then at a slope of about 1 in 9. (5) The mud-covered *Sea Floor* is reached at about 1045 feet. Only the beginning of this region was surveyed where the slope is about 1 in 27.

PHYSICAL CONDITIONS ALONG TRAVERSE I.

Some of the main physical conditions prevailing along the traverse which may influence reef organisms may now be considered. These are correlated with the levels of the traverse which have already been noted, and the manner in which water is held up in the moat at low tide. Tidal and diurnal changes are of much greater importance than seasonal variations.

The conditions within and without the Boulder Tract at low water are very different, and on the reef flat show very large diurnal and seasonal differences. Within the Moat the water is almost stagnant, whereas outside calm and rough water alternate according to the weather.

The Boulder Tract is swept by the broken-water surface, and the higher rocks and



b

TEXT-FIG. 2.—Level sections across the edge of Low Isles reef, vertical and horizontal scales being equal. (a) Section along Traverse I from the edge of the Moat across the Boulder Tract and Seaward Slope, passing over the Sea Floor beyond the end of the Traverse. (b) Section along a line extending through C beacon and B beacon (see Text-fig. 1) and projected across the reef edge and over the sea floor. The section starts at 390 feet seawards of B beacon. "X" marks the Coral Head, which is shown in the large-scale map on Plate XII. It is clear that the downward slope is more gradual on the leeward side of the island (a) than on the northern side (b).

coral heads outside it are always freely exposed to moving water. Below a depth of 7 feet below datum water movement usually appears to be lessened, and a considerable amount of sediment in the form of fine grey mud lies on rock surfaces in increasing thickness down the reef slope. Details of the composition and deposition of sediments on Low Isles are given by Marshall and Orr, Vol. I, No. 5 of these reports. In the Moat considerable sedimentation takes place, but sediment collected in jars appears to arise mainly from a to-and-fro movement disturbing the moat sand, rather than from actual new deposition. This shifting sediment has here buried and killed the bases of many of the larger corals. Seaward of the Boulder Tract the rate of sedimentation is usually less than in the Moat. In both localities the sediment is composed of sand and fine detritus or mud. In the Moat the bulk of the sediment (95%) is composed of coarse calcareous material. Outside the Boulder Tract much more fine material is deposited, the mud containing a high but variable percentage of non-calcareous matter.

The ranges of temperature in the moat and outside the Boulder Tract are very different. The outside water at a depth of 1 metre fluctuates between about 20° C. in winter and 31° C. in summer, with a daytime rise of 0.3–2.5° C. Within the Moat the daily temperature range is much greater, approximating more closely to air temperatures. In the daytime in the summer the Moat may reach 37.5° C. and at night in winter 18° C. During low water there is no circulation of water into the Moat from outside which might modify the temperature extremes, but since there are two sets of tides a day the temperature seldom reaches levels at which corals cannot survive.

The composition of water inside and outside the Boulder Tract (see Orr, Vol. II, Nos. 3 and 4) at low water is different. Diurnal changes in the Moat are greatest at spring tides and least at neaps. The outside water is more uniform, and at a little distance from the reef shows little diurnal variation. In the Moat during the daytime low water there is a variation in salinity, oxygen content, pH and excess base. During the winter salinity changes are unimportant, and evaporation may cause a rise from 35‰ to 36‰. During the summer, after heavy rain the maximum reduction was to 17‰ in a sandy pool containing little coral on the Reef Flat. The lowest record for the deeper part of the Moat was 27‰, but that was not on an extreme occasion. The lowest oxygen content recorded was 18% saturation and the highest 278%. The pH falls at night and rises during the day, the range being 7.8–8.9. (Full details of variations in the Western Moat and elsewhere are given by Orr in Vol. II, No. 4 of these reports.)

The amount of food available for corals in the form of plankton (see Russell and Colman, elsewhere in these reports) shows no striking difference in richness in the water over the reef flat and beyond the edge of the reef. When the tide is high there is plenty of plankton immediately over the coral, both in the day, when the light is bright, and at night when the coral is feeding. Most of the reef-flat plankton appeared to be similar in quality and relative quantity to that found 3 miles from the reef. However, during periods of low water the small volume retained in the moats must greatly reduce the available plankton.

DETAILED ACCOUNT OF THE SUBSTRATUM, CORALS AND ALGAE OF TRAVERSE I.

The distribution of corals is little affected by the seasons, but the algal growth varies considerably during the year. The survey was made during April–July, 1929, so that details of algae refer to these months only.

Graphs 1-40 (Plates I-IV illustrate the total numbers of coral colonies and also the numbers of species of corals and algae on each square yard of the traverse. Where branching corals are recorded in terms of the area covered, one square foot of coral for numerical purposes has been taken as equivalent to one separate colony. Many species of *Favia*, *Leptastrea*, *Goniastrea* and *Coeloria* will collectively be referred to as *Favia*. Algae which could not be counted individually are represented graphically as present or absent on each square yard. Some of the smaller algae whose distribution and identification is uncertain will not be mentioned.

Unless otherwise stated the descriptions below refer to conditions prevailing at low water.

(1) *The Thalamita Flat.* 0-25 feet. 2.8 feet above datum.

The exposed reef flat is uneven with flat slabs of coral rock, small boulders and fragments scattered on the sand, and water lying in the shallow sandy puddles between the rocks. A few living *Hippopus* (Graph 4) are present, projecting well out of the water.

The rocks are covered by minute and encrusting algae, and the flowering plant *Thalassia Hemprichii* is scattered in the sandy puddles (see Graphs 1 and 5). The most conspicuous elements of the flora are the red algae, mainly *Acanthophora spicifera*, which together with *Laurencia papillosa* and *Roschera glomerulata* form a dense covering on the rocks a few inches in length, but the exposed *Hippopus* shells are not overgrown by algae of appreciable size. Brown algae are small and few, being represented mainly by *Turbinaria* and occasional large and small tufts of *Padina* on the rocks (see Graphs 9 and 10). Green algae are more conspicuous than the brown. *Boodlea paradoxa* and *Halimeda Opuntia* occur on nearly every square yard, the former often quite luxuriant, but *Halimeda* only as poor tufts. *Dictyosphaeria favulosa* and other species of the genus are also fairly abundant.

Corals are entirely absent from the first three yards of the flat. Towards the moat in the puddles three small knobs of massive *Porites* are present 1-2 inches in diameter (see Graphs 2, 3 and 19).

(2) *The Moat.* 25-700 feet. 2.4-1.8 feet above datum.

The moat gradually deepens and then shoals fairly suddenly on to the Boulder Tract (see level section). In the shallower part the water is 0.2-0.4 feet deep, and in the deeper part reaches 0.9 feet. The bottom is uneven and sandy, and bears occasional submerged or slightly projecting slabs of coral rock and small fragments. Salinity, temperature and other changes are at a maximum in the shallower part of the moat.

The outstanding features of the moat are the abundance of algal growth in the shallower part (see Graph 1), and in the deeper part the occurrence of flat-topped platforms of living coral formed by both massive and branching forms which cover much of the bottom (see level section, Graph 16, and large scale map, Plate IX). The area covered by such platforms increases as the moat deepens. Dead massive coral platforms provide sites for fresh coral growth upon their sides (see Plate IX). *Hippopus* occur only in the shallower part (see Graph 4), and its shells form sites for the growth of algae and small corals. Near the Boulder Tract the narrow zone of shallow water does not support abundant algae as does the wider zone of shallow water towards the Flat.

The sandy areas are most thickly covered by *Thalassia Hemprichii* in the shallower

part, and as the available spaces become reduced as coral growth increases, so the abundance falls off (see Graph 5: the uneven peaks on the graph are caused by the alternation of sandy and more rocky areas). *Thalassia Hemprichii* is not found in the sand between the richest coral growth. *Halophila ovalis* appears between 125 and 513 feet, and becomes increasingly common in the sand along with *Thalassia Hemprichii*.

The abundance of algae reaches a maximum at 150–183 feet in the middle of the shallower part, and then progressively decreases as the moat deepens, where algae no longer form a conspicuous living component on the reef (Graph 1). Microphytic algae cover the rocks, and the submerged *Hippopus* shells are densely covered by algae.

In the shallower part, as on the flat, the red algae *Laurencia papillosa* (Graph 12), and *Acanthophora spicifera* (Graph 14) form a large proportion of the algal growth, reaching a maximum at 150–180 feet. As the water deepens slightly, others, such as *Amphiroa fragilissima* (Graph 13) and *Laurencia obtusa* (Graph 15), appear in increasing quantity, but in the deeper part all these species decrease in size and abundance as illustrated by the graphs. *Roschera glomerulata* (Graph 11) on the contrary progressively decreases beyond the flat. *Corallopsis* (?) and *Galaxaura*, however, are found discontinuously along most of this section up to 644 feet.

The largest of the brown algae, *Sargassum lanceolatum* and other species, are attached to rocks in the shallower part, and soon reach their maximum size at about 60 feet (Graph 8). Where suitable rock sites are available up to three large plants about 2.6 feet long may be present on one square yard. Further along the traverse they decrease in size, although the small plants present may be more numerous; *Hydroclathrus* occurs occasionally and other brown algae become more frequent. *Padina* (Graph 9) reaches its maximum density between 215 and 250 feet where the tufts are all large and up to 35 present per square yard. It occurs on rocks and also as an epiphyte upon *Sargassum*. Small *Padina* persist in the deeper part except between 504 and 600 feet. It becomes more abundant again as the moat merges on to the Boulder Tract (Graph 9), where algae other than a few greens do not occur. *Turbinaria*, unlike other algae, continues to increase as the moat deepens, and then suddenly becomes almost absent after 492 feet (Graph 10). A few specimens of *Digenea simplex* occur, and brown algae, other than *Padina*, are not found in the deeper part beyond 306 feet.

Among the green algae (Graph 7) *Anadyomene Brownii* resembles *Sargassum* in its distribution, and reaches its maximum in the shallower part, thereafter becoming scarcer and smaller (Graph 6). *Halimeda Opuntia* occurs on nearly every square yard in the shallower part, up to 24 large tufts being present on one square yard. *Boodlea paradoxa* is present on most square yards in the shallower part and almost disappears beyond 306 feet. *Dictyosphaeria favulosa* and allied species occurs occasionally up to 400 feet and then more rarely. *Bornetella nitida*, at first scarce, occurs occasionally except in the deepest parts, and becomes larger and more frequent between 200 and 240 feet. *Caulerpa*, represented mainly by *C. racemosa*, but sometimes by *C. sertularioides* and *C. cupressoides*, occurs on six square yards and is large in the middle of the shallower part. Green algae, except for small tufts of *Halimeda*, are absent from the deeper part, and towards the Boulder Tract species of *Dictyosphaeria*, *Boodlea paradoxa* and *Anadyomene Brownii* reappear in the shallow water.

Quantities of filamentous diatoms, such as *Biddulphia pulchella*, etc., occasionally form long tufts on the rocks and on living and dead corals.

Corals are few and small in pools in the shallower part, and increase to a maximum between 570 and 610 feet (see Graphs 2 and 3). This zone appears to lie beyond the deepest region, but where corals are thickest much dead coral debris accumulates on the sandy spaces between, so reducing the depth of water.

In the shallower part the bulk of the corals comprise massive *Porites* in small colonies 1-4 inches across and up to 15 in number on one square yard, *Leptastrea roissyana* 1-2 inches across and *Goniastrea pectinata* 1-4 inches across (see Graphs 19, 21 and 22).

In the deeper part *Montipora ramosa* becomes increasingly extensive. When the colonies reach the water surface their upward growth is checked beyond a maximum of 0.3 feet above the low-water level in the moat, and so flat-topped platforms are formed which rise highest in the middle of this region and may cover the whole width of the traverse (see level section and Plate IX). Only parts of the platforms are now living, as is shown by a comparison of graphs 16 and 17 of the distribution of platforms and living *M. ramosa*. Dead platforms are most extensive in the deepest parts. Outside the traverse *Acropora hebes* forms similar platforms (see also map of Acropore Moat, Plate X). Massive corals become progressively more extensive, and their upward growth is similarly checked, but at a slightly lower level; their tops die just above low-water level, forming flat platforms of some size with living vertical sides. The majority of platforms one square yard or more in area are formed by species of massive *Porites*, while species of *Favia** form smaller platforms rising to the same height. Massive *Porites* is fairly evenly distributed (Graph 19), and the size increases until platforms 10-30 inches across are formed. Beyond 600 feet only small knobs (1-3 inches) occur, although at about 640 feet large dead platforms are present. The levels of the platforms are given in the tables, p. 309.

Species of *Favia*, *Leptastrea*, etc., become most abundant between 560 and 610 feet, where available spaces are not covered by *M. ramosa* platforms (Graphs 16 and 20). Table I gives the species present, together with the numbers and sizes of the colonies. *Leptastrea roissyana* and *Goniastrea pectinata* become larger than in the shallower part, the former occurring more frequently (see Graphs 21 and 22). The Shoaling Moat near the Boulder Tract supports mainly *Favia* and *M. ramosa*.

Other corals occurring entirely or largely in the deepest parts of the Moat are *Pocillopora bulbosa* (1-8 inches), *Galaxea musicalis* (3-6 inches), *Psammocora gonagra* (1-10 inches), *Platygyra phrygia* (3-5 inches), species of *Acropora* (mainly *A. hebes*, *A. pulchra*, *A. quelchi* and *A. squamosa*), *Symphyllia* (3-8 inches), *Fungia*, *Cyphastrea* (2-7 inches), and *Coeloria* (see Graphs 25, 18, 29, 30, 28 and 26). They are found on dead faces of the massive coral platforms and on rocks between the extensive growth of *M. ramosa*.

A large-scale map of a portion of the Madrepor Moat is given in Plate X for comparison with the deeper part of the Western Moat, which is crossed by the survey (Plate IX). The bottom levels of the two moats in these positions are similar, lying at 2.1 feet and 2.0 feet above datum respectively. The physical conditions of the two regions show no marked differences, but there is more movement of sediment in the Madrepor Moat. However the corals and plants of these two regions are unlike; their growth, as seen in the mapped areas, appears to be of more recent date in the Madrepor Moat than in the Western Moat. The bottom of the Madrepor Moat is sandy, with little dead coral material

* Unless details of species are given the term "*Favia*" refers to *Favia* and other genera of closely similar external form, such as *Goniastrea*, *Leptastrea* and species of *Coeloria*, which are not conspicuously meandrine.

TABLE I.—*Species of Favia, Goniastrea, Leptastrea and Coeloria in the Moat on Traverse I.*

Coral.	Diameter of colonies in inches.	Numbers of colonies.
<i>Leptastrea roissiana</i>	1-12	105
<i>Goniastrea pectinata</i>	1-7	72
<i>Goniastrea retiformis</i>	1-12	73
<i>Favia favius</i>	1-9	65
<i>Favia abdita</i>	1-9	44
<i>Favia astraeiformis</i>	2-10	40
<i>Favia doreyensis</i>	1-6	23
<i>Coeloria daedalea</i>	2-9	20
<i>Favia K.18*</i>	2-7	18
<i>Favia hahicora</i>	2-7	18
<i>Goniastrea</i> sp.	4	1
<i>Favia clouei</i>	5	1

Nearly half of the colonies of *Goniastrea* and *F. astraeiformis* occur between 564 and 600 feet and between 600 and 625 feet respectively, while almost all the *Coeloria daedalea* occur between 620 and 700 feet.

* This species could not be satisfactorily determined, and is so labelled in the collection deposited in the British Museum.

on the surface, either as debris or rock, which could form suitable surfaces of attachment for living corals. The corals present are mainly platforms of *M. ramosa* and *A. hebes*, both of large size and entirely living, and some massive *Porites* which have not yet reached the water surface and formed platforms with dead tops. The algae are fairly numerous and *Thalassia Hemprichii* is abundant in the sand. The map of the Western Moat in contrast shows abundant dead coral material forming a rocky substratum for the attachment of other corals, a much richer variety of corals and very few algae. It may be noted that on the survey of Low Isles made by H.M.S. "Penguin" in 1905 no definite moat is shown where the Madrepor Moat now is, although the Western Moat is shown on the plan. It is probable that the Madrepor Moat shows a young stage of the same formation seen in the Western Moat.

(3) *The Boulder Tract.* 700-846 feet. <2.9 feet above datum.

The Boulder Tract here gradually rises from 2.6 feet, reaching 2.9 feet above datum at 755 feet. Thereafter it slopes more steeply downwards to 0.4 feet above datum at 846 feet. The substratum is composed of coral rocks and fragments with finer material between them. The rocky surface is fairly regular up to the crest, but beyond it irregular blocks of rock become larger and more frequent and may project 1.6 feet above the general level (see level section). The boring clam *Tridacna crocea* occurs in increasing abundance in these rocks (Graph 40). Gravelly sand lodges between the larger slabs of rock from 700 to 724 feet, and thereafter loose coral debris, such as composes the ramparts, lies over and among the rocks. Beyond 800 feet sand appears between the boulders, and water is held up in the small hollows.

A thin growth of microphytic algae is generally present, becoming thicker in the damper regions beyond 830 feet. Other algae are very small and limited to the lower or damper parts, being most frequent near the moat and scarce towards the Seaward Slope (see Graph 1). Isolated specimens of the red algae *Laurencia papillosa* (Graph 12), *L. obtusa*, *Galaxaura lapidescens* and *Amansia glomerata* occur towards the Seaward Slope. Small stunted *Padina* (Graph 9), and green algae (Graph 7) such as *Boodlea paradoxa*, *Dictyosphaeria favulosa* and other species and isolated specimens of *Bornetella nitida* and *Halimeda Opuntia* are found only on the slope towards the Moat. Blue-green algae, such as *Lyngbya majuscula*, are abundant locally on the damper parts of the Seaward Slope.

Corals are absent from the dryer parts of the Boulder Tract and appear again towards the Seaward Slope beyond 800 feet, small colonies of massive *Porites* and a few species of *Acropora* and *Favia* being present. At about 830 feet the rocks dip below low-water level, and corals then begin to increase (see level section and Graphs 2 and 3). *A. hebes* (Graph 31) is the dominant acropore at this upper limit of coral growth, but as the water deepens *A. squamosa*, *A. gemmifera* and *A. quelchi* make their appearance (Graphs 33 and 35), and also *Favia astraeiformis*, *F. favus* and *Goniastrea retiformis*.

Alcyonaria here make their first appearance (Graph 39) with two small colonies of *Sinularia polydactyla* and one of *Lobophytum crassum*.

(4) *The Seaward Slope.* 846–1045 feet. <16·8 feet below datum.

The reef slopes downwards here a little more steeply to a depth of 8·5 feet below datum at 1014 feet. Then follows a steeper slope descending to 16·8 feet below datum at 1045 feet. These two parts of the slope will be considered separately. The steeper slope drops downward at about 1 in 4·3 at first, and then at a slope of 1 in 9. Large coral heads projecting upwards 8 feet or more are only borne on the landward part of the slope up to 1014 feet, and the steeper part of the slope appears to coincide with the seaward limit of coral heads outside the traverse.

(a) *Landward Part of the Seaward Slope.*—The surface is composed of low coral rocks with occasional large boulders, the tops of which rise almost to low-water level and bear luxuriant coral growth forming "coral heads". The faces of such coral heads often slope downwards gradually towards the boulder tract and precipitously on their seaward faces (see boulder at 915 to 918 feet on level section). Between the low flat rocks and coral heads at 846 to 921 feet lie some clean sandy gaps. From 922 to 963 feet the rocky bottom becomes extremely rough. No sandy patches occur, and the rock surface is fairly clean. Uneven rocks then continue from 963 to 1014 feet with a large coral head at 1009 to 1014 feet, and others lying on either side of the traverse. A little blackish sand here appears between the boulders and a thin layer of grey mud lies on the rock surfaces.

Algae of any size are absent from this region onwards. Microphytic forms grow on the higher rocks which are not mud-covered, and otherwise only one small *Polysiphonia* was found (Graph 1).

The outstanding feature of this zone is the abundant coral growth on the higher parts of the slope and on the coral heads. Alcyonaria also become numerous (Graph 39). The numbers of species and of colonies of corals here reach their maxima for the traverse (see Graphs 2 and 3). The rocks are well covered by living coral up to 921 feet, and beyond more bare rock surface is present. The increasing depth enables a luxuriant growth of

projecting brackets of coral to be formed on the sides of the rocks, one above another, and bush-like growths to invade the sandy pools, while the upper parts of the larger boulders are densely covered (see large-scale map on Plate XI, *a*). The peaks on the graphs coincide with the larger coral heads seen in the level section. The region of greatest coral growth and of most numerous species per square yard of available space lies about 2 feet below datum.

Species of *Acropora* rapidly increase to a maximum between 846 and 890 feet (Graph 30), where each is found in a variety of positions, and shows no tendency to make platforms or other growth forms at definite levels as in the moat. A zoning of the more abundant species is apparent down the slope, as is indicated in Table II and Graphs 31–35. Other species less frequent in occurrence are *A. variabilis*, *A. hyacinthus*, *A. rosaria* and *A. formosa*. They are found mostly in the shallower water to 890 feet, but the last two also extend into deeper water to 976 feet. From 921 feet Acropores become few, and beyond 976 feet are practically absent.

TABLE II.—*The more Abundant Species of Acropora on the Seaward Slope of Traverse I.*

Species.	Level of maximum growth.	Remarks.
<i>A. hebes</i> . . .	0·8 ft. above datum .	Does not occur beyond 828 feet.
<i>A. gemmifera</i> . . .	0·4–1·2 ft. below datum .	Not very abundant.
<i>A. polymorpha</i> . . .	1·2 ft. „ „ .	Forms extensive growths of 1 sq. yd. or more, the tops lying at various levels. It does not extend to deeper water.
<i>A. squamosa</i> . . .	1·2 ft. „ „ .	Abundant, forming brackets and platforms 3–18 inches across.
<i>A. exilis</i> . . .	1·6 ft. „ „ .	The most abundant species as measured by the number of separate colonies. It forms bush-like growths 3–12 inches across.
<i>A. quelchi</i> . . .	2 ft. „ „ .	Gradually increases in size as the water deepens to this level, and forms flat-topped brackets 2–18 inches across. It is also present near the surface on the large coral heads.

Favia, *Leptastrea*, etc., become increasingly abundant in number and species as the water deepens, and cover the rock surfaces not overgrown by Acropores (Graphs 20 and 30). They are particularly numerous on the larger boulders and coral heads (Plate XI, *a* and level section), but apart from these situations they are not so abundant as in the Moat, and become fewer and smaller in the deeper parts. Table III shows the species present, together with the numbers and sizes of the colonies and some remarks on their individual distribution. Of the two species common in the shallower part of the Moat, *Leptastrea roissyana* (Graph 21) is present, while *Goniastrea pectinata* does not here occur at all (Graph 22). *Goniastrea* K. 18,* present in the Moat, is here absent; other species found

* This coral could not be satisfactorily determined, and is so labelled in the collection deposited in the British Museum.

in the Moat are either more or less frequent in different parts of the Seaward Slope, while *Favia vasta* and *Favia clouei* appear only on the deeper parts of the Seaward Slope (Graphs 24 and 23).

TABLE III.—*Species of Favia, Leptastrea, Goniastrea and Coeloria on the Seaward Slope of Traverse I.*

Species.	Size of colonies in inches.	Numbers of colonies.					Remarks.
		846–888 ft.	888–930 ft.	930–972 ft.	972–1014 ft.	1014–1045 ft.	
<i>Leptastrea roissyana</i>	1–6	0	7	3	1	0	Scarcely occurs in the richest coral zone, but extends to the deeper parts, much as it does into the shallower part of the Moat.
<i>Goniastrea retiformis</i>	1–16	10	9	5	2	1	} As in the Moat, these are most numerous species, but they here attain a larger size.
<i>Favia abdita</i>	1–7	4	5	4	4	0	
<i>Favia astraeiformis</i>	2–12	2	9	9	3	0	
<i>Favia fавus</i>	2–7	3	10	10	10	1	Is more frequent than in the Moat and here persists into deeper parts as small colonies.
<i>Goniastrea</i> sp. K. 5*	2–10	7	4	0	4	0	Scarce in the Moat, but here more frequent in the shallower parts.
<i>Favia halicora</i>	3–8	2	6	4	2	0	Generally distributed here as in the Moat.
<i>Favia doreyensis</i>	2–6	4	2	2	4	0	Less frequent than in the Moat, and here larger in the shallower parts.
<i>Coeloria daedalea</i>	3–7	4	2	2	0	0	Does not extend to deeper water.
<i>Leptastrea ehrenbergiana</i>	2–7	2	0	2	0	0	Scarce.
<i>Favia</i> sp.†	4–6	0	2	0	1	0	Scarce; appears to be a deeper water form.
<i>Favia vasta</i>	3–7	0	0	3	4	0	} Become more frequent in deeper water, but are absent elsewhere.
<i>Favia clouei</i>	2–12	0	2	9	9	1	

* This species could not be satisfactorily determined, and is so labelled in the collection deposited in the British Museum.

† These specimens have not been satisfactorily determined, and have been referred to either *F. Hemprichii* or *F. hirsuta* by Prof. Matthai.

Massive *Porites*, at first scarce and small, becomes more numerous in the richest coral zone, reaching 12 inches across, and is present occasionally throughout this section (Graph 19).

Of the other corals present in the Moat, *Psammocora gonagra* does not appear on the Seaward Slope (Graph 18). *Pocillopora bulbosa* occurs in scattered colonies (2–12 inches), but beyond 420 feet in the deeper water is replaced by *P. danae* (Graph 25). *Cyphastrea chalcidicum* (3–6 inches, Graph 26), *Symphyllia* (3–12 inches, Graph 28), *Coeloria* sps. and *Platygyra phrygia* occur mainly between 860 and 960 feet, and are more frequent and larger than in the Moat. *Montipora* (Graph 27) is abundant between 860 and 920 feet. It is mainly represented by encrusting growth forms from which arise fan and pillar-shaped upgrowths which may cover several square yards. *Galaxea musicalis* (3–7 inches) beyond 886 feet becomes large and abundant, and after 945 feet the large polyped *G. fascicularis* is usual (Graph 29).

Corals making their first appearance on the traverse are *Lobophyllia* sp. (2–12 inches), *Stylophora pistillata* (Esper) (6–12 inches) and *Astreopora* sp. (3–7 inches), see Graphs 36–38; with occasional *Hydnophora* sp., *Heliopora*, *Merulina ampliata*, *Favia acropora*, *Turbinaria* sp., *Echinopora lamellosa* and *Millepora* sp. In the deeper parts *Echinopora gemmacea* is present; while *Pavona cactus* occurs occasionally in the shallower regions (*Pavona*, *Hydnophora*, *Echinopora*, *Lobophyllia* and *Merulina* are occasional in the Moat outside the traverse).

As the Seaward Slope deepens, the appearance of mud lying on the rocks in increasing thickness coincides with the reduction and final disappearance of *Acropora*, *Favia* and *Montipora*. In the deeper parts the dominant corals are *Stylophora*, *Lobophyllia*, *Astreopora* and *Galaxea fascicularis*, with a few *Echinopora gemmacea*, *Favia fava*, *F. vasta*, *F. clouei*, and the branching "*Porites Queenslandiae duodecima*" of Bernard.

The maximum growth of the Alcyonaria coincides with that of the corals (see Graphs 39 and 3). The following forms occur, but their distribution shows no marked zonation: *Lobophytum crassum*, *Simularia polydactyla*, *Lobularia pachyclados* and *Simularia lochmodes*. The Zoanthid *Palythoa* is here found occasionally.

The large-scale map on Plate XII shows the corals and Alcyonaria situated on the vertical face of a coral head lying off the N.E. corner of Low Isles. The position of the coral head is shown in Text-fig. 2b, "X". This coral head is just covered at low water springs, and the bottom round it is composed of clean coral debris containing little mud. The coral heads on and around the landward part of the Seaward Slope of Traverse I show similar coral growth upon their sides, but owing to the muddy bottom their bases are more barren; and since their tops are at a higher level, their upper parts bear a more abundant growth of Acropores. It may also be noted that although the rock surface is not completely covered, there is a greater variety in the species of coral present compared with those found on the shallower and more densely covered rocks seen in Plate XI, a.

(b) *The Steeper Part of the Seaward Slope.*—Beyond the coral head at 1009 to 1014 feet, the gentle slope becomes steep for a short distance (see level section and p. 279). A few boulders are present, but no more large coral heads, and the rocky bottom becomes less uneven. On this steep slope few fragments of coral rock lie on the rough surface, which is covered by a thick layer of easily disturbed mud.

Algae large enough to be detected from a diving helmet are absent.

Corals are now very few and small, and most are of massive growth form. They are situated mainly on the steeper rock faces and comprise the types found on the deeper parts of the landward part of the slope, *Astreopora* (2–8 inches) and massive *Porites*, often of large size (30 inches), being the most frequent (Graphs 38 and 19).

Acropora, *Montipora* and *Pocillopora* are absent. *Favia* are few, and *Galaxea* is almost restricted to the landward part of the slope (see Graphs 30, 27, 25, 20 and 29). Small specimens of the following are also present: *Lobophyllia* (2–8 inches), *Goniopora* (2–3 inches), *Turbinaria* (2 inches), *Stylophora pistillata* (3–6 inches), encrusting *Millepora* (3 inches) and *Merulina ampliata* (4 inches) (see Graphs 36 and 37). The mud lying on the rocks appears most unfavourable to corals, which apart from *Goniopora*, *Turbinaria* and *Stylophora pistillata* form small encrusting colonies, the tops of which may only just reach the surface level of the mud. The corals are clean but their edges may be dead, and they appear to be on the verge of being smothered by the mud.

A few Alcyonaria are present, mainly *Simularia flexibilis* and *Lobularia* sp.

(5) *The Sea Floor.* 1045–1089 feet. < 18.6 feet below datum.

The muddy sea floor is here reached, the even bottom sloping gently downwards. A little coral debris lies on the mud, and a few small rocks and two living boulders of massive *Porites* (30 inches) are present. Other corals and Alcyonaria are almost absent. Two *Astreopora* (16–20 inches, Graph 38) and single colonies of *Turbinaria* (3 inches), *Merulina ampliata* (3 inches), *Coeloria* (6 inches), *Sarcophyton trocheliophorum* (7 inches) and *Lobularia* sp. (6 inches) occur on the *Porites* boulders and small rocks (Graph 39). The mud is practically devoid of surface life. One large *Polyphyllia talpina* 34 × 7 cm. and some orange-coloured starfish (*Iconaster longimanus*) lie on the mud, and one clump of the alga *Digenea simplex* is present. The presence of the free fungiid *Polyphyllia* on the mud is remarkable, as this heavy coral must be successfully climbing upwards, with its cilia in continual movement, so counteracting its tendency to sink in the soft mud. The whole colony was in perfect condition, and showed no basal dead region as do most of the fixed corals. (See also the ability of *Fungia* to climb through sediment, Marshall and Orr, Vol. I, No. 5.)

Beyond 1045 feet the muddy sea floor appears devoid of rocks, corals and Alcyonaria, and the survey was discontinued after 1089 feet.

THE SURVEY OF TRAVERSE II.

The strip of reef examined along this traverse passes from the beach of the sand cay in a north-easterly direction across the reef (Luana reef, see Text-fig. 1), to end on a comparatively bare sandy stretch of bottom. A level section along the traverse is given with the graphs showing the distribution of organisms. The depth of water lying over the whole of the traverse varies directly with the state of the tide.

The traverse may conveniently be divided into the following portions for subsequent consideration: (1) *Beach Sand*, 0–52 feet, extending from the cay seawards, descends steeply from 12 to 5.5 feet above datum at a slope of 1 in 8. The sand is loose and devoid of corals and algae. (2) *Beach Sand-rock* ("beach rock" on Text-fig. 1) follows from 52 to 162 feet. Flat slabs of rock slope downwards to 1.4 feet above datum, and the rock is then broken away between 110 and 136 feet (see Text-fig. 1, and "m. 1." on level section). A narrow part of the Northern Moat lies just beyond the Sand Rock ("m. 2" on level section), and merges into (3) *The Inshore Part of the Reef*, an almost level area considerably overgrown by coral. It extends from 171 to 302 feet, sloping slightly from 1.2 to 0.8 feet above datum. Thereafter the downward slope increases over (4) *The Seaward Slope* from 302 to 500 feet, until the flat sandy bottom is reached at 5.2 feet below datum. This slope presents many irregularities in the form of masses of coral rock or living coral, so obscuring its true level, which is only revealed by the bottom levels of the sandy pools and the gaps between the irregular rocks (see level section, Plate V).

This traverse may be compared with that portion of Survey I which passes seawards from the Boulder Tract. The main differences between the two are correlated with the differences in profile, that of Survey I descending to about 18 feet below datum, while that of Survey II slopes gently to about 5½ feet below datum in about the same horizontal distance.

PHYSICAL CONDITIONS ALONG TRAVERSE II.

The physical conditions here show less variety than along Traverse I, and mainly resemble those existing on the *Seaward Slope* of the latter. The reef lies in protected water (see Text-fig. 1), except occasionally during the summer; the influences of moving water must be here at a minimum for Low Isles, and breakers are usually absent. The extremes of water level are indicated in the level section. At low spring tides the level Inshore Part of the reef dries out for a short time, but such tides only expose the tops of the higher rocks along the Seaward Slope. During low neap tides, when the reef is not fully exposed, the water remains shallow over the Inshore Part for considerable periods. Here conditions are at times obtained which may approach those prevailing in the Western Moat, but over a substratum at about 0·8 instead of about 2 feet above datum, and in a position open to deeper water instead of shut off from it. The Northern Moat ("m. 2.") at the point where the section crosses it is so narrow that it merges into the level Inshore Part of the reef both in its physical conditions and in the corals which it supports.

The diurnal variations in temperature, salinity and chemical composition of the water (see Orr, Vol. II, No. 4, p. 92 of these reports) are much smaller than on the Reef Flat, but are still considerable, and contrast with the deeper outside water beyond growing coral where such variations do not obtain. Seasonal variations are also less extreme than on the Reef Flat, and approach those present in the outside waters. The rate of deposition of sediment on the sandy stretch at the end of this traverse was usually less than in the Western Moat (see Marshall and Orr), and much finer in grain. No mud is present on the bottom on any part of this traverse, possibly owing to the small depth of the reef; and sediment probably does not here constitute a limiting factor for coral growth.

DETAILED ACCOUNT OF THE SUBSTRATUM, CORALS AND ALGAE OF TRAVERSE II.

The general remarks made for Traverse I (pp. 281–2) respecting the interpretation of the graphs and the season at which the survey was made are also applicable here. The peaks on the graph showing the distribution of coral colonies are less uneven than those on Traverse I, owing to the absence of large Coral Heads and extensive vertical faces of rock available for coral growth. Few *Hippopus* shells upon which corals and algae can become attached are present.

(1) *The Beach Sand.* 0–52 feet. 12–5·5 feet above datum.

Needs no further comment.

(2) *The Beach Sand-rock.* 52–110 feet and 136–162 feet. 5·5–1·4 feet above datum.

The rock here is smooth, flat and shelving. At first the slabs may lie at different levels, but all slope downwards at about 1 in 15. Beyond 107 feet the rock breaks up somewhat and sand appears upon it. The isolated patch of rock at 136–162 feet is much broken up by vertical cracks into flat slabs. These rocks are exposed for long periods at low water, and support a covering of slimy microphytic algae and a few rock oysters.

Where the rocks dip down to the arms of the Northern Moat ("m. 1." and "m. 2." on level section), a few red, brown and green algae appear (Graphs 41 and 46). Between 94 and 110 feet small *Padina* form the bulk of the few algae (see Graph 47); *Amphiroa fragilissima*, tufts of filamentous diatoms and some blue-green algae also occur.

Between 110 and 136 feet the rock is broken away, leaving a sandy area sinking to 0.8 feet above datum (see Text-fig. 1, and level section "m. 1."). Except at extremely low tides this is a sandy pool connected with the Northern Moat, and a few rock fragments lie freely on the sand. Algae are few and small, but more varied than on the beach sand-rock (see Graph 41). The submerged rocks bear a thicker covering of microphytic algae than those which are exposed, and filamentous diatoms are everywhere present. Green algae, represented by *Bornetella nitida*, appear in the middle of the pool (Graph 46). The brown algae are most frequent at the sides. *Padina* is the commonest (Graph 47), but *Colpomenia* and *Hydroclathrus clathratus* are also present as small isolated specimens. Red algae, such as *Galaxaura lapidescens*, *Amphiroa fragilissima*, *Laurencia papillosa* (Graph 48) and *Roschera glomerulata* occur in all parts of the pool, but are isolated and small in size. Two colonies 2 inches across of *Favia astraeiformis* and *Pocillopora bulbosa* are present (Graphs 52 and 53). A narrow arm of the Northern Moat ("m. 2." on level section), sinking to 0.4 feet above datum, lies between the beach sand-rock and 171 feet. The bottom is sandy, with few rocks and fragments. The corals and algae here resemble those of the following section, with which they will be considered.

(3) *The Inshore Part of the Reef.* 171–302 feet. 1.2–0.8 feet above datum.

Beyond the Moat the Inshore Part of the reef rises to about 1.2 feet above datum. The outstanding feature here is the growth of flat-topped platforms of branching coral, such as are seen in the Western Moat, and which here rise to 1.6 feet above datum (see level section). Seawards from the Moat the reef gently descends to about 0.8 feet above datum, where the coral platforms become more scanty. Finally the level drops abruptly to datum during the last 12 feet. The bottom, where not covered by coral platforms, is mainly sandy, with flat rocks and fragments in places. Only two *Hippopus* are present.

Unlike the Western Moat, very little *Thalassia Hemprichii* occurs in the sand between the coral platforms (Graph 45), and *Halophila ovalis* is absent.

The number of species of algae rises in the arm of the moat and decreases again when the coral platforms are most extensive. The maximum flora, both in variety and bulk, lies in the middle of this region where coral growth is smallest (see Graphs 41 and 42). The green algae are fairly evenly distributed (Graph 46). *Halimeda Opuntia* is present on every square yard and is often abundant, but becomes less extensive towards the Seaward Slope. *Halimeda macroloba* and species of *Dictyosphaeria* are fairly frequent, and *Bornetella nitida* becomes most numerous in the middle of this region. *Boodlea paradoxa*, *Caulerpa racemosa*, *C. sertularioides* and *C. cupressoides* are scarce, appearing two or three times. Brown algae are represented mainly by *Padina*, which becomes increasingly abundant as the *M. ramosa* platforms decrease, and then disappears suddenly beyond 286 feet (Graph 47). *Hydroclathrus clathratus* and *Digenea simplex* are occasional. The red algae are few. *Galaxaura* shows the same type of distribution as *Padina* (Graph 47), *Laurencia papillosa* and *Acanthophora spicifera* are not abundant (Graphs 48 and 49). *Gracilaria Textorii* and *Amphiroa fragilissima* are scarce and small, and *Galaxaura marginata* and *Amansia glomerulata* occur once or twice.

Filamentous diatoms are frequent, forming hair-like tufts.

The total number of coral species present per square yard increases fairly steadily along this section (Graph 43). The flat-topped platforms are entirely composed of branching corals, and, unlike those of the Western Moat, are almost all living. *Montipora ramosa* is the most extensive form, invading the Northern Moat and almost completely covering parts of the Inshore Reef to the exclusion of other coral and algal growth (Graph 50). *Acropora hebes* may also give small areas of platform (Graph 59). Other corals are at first few, some small *Leptastrea roissiana*, *Favia astraeiformis*, *Goniastrea* sp., *Cyphastrea chalcidicum* (1–4 inches) and one *Montipora foliosa* appearing (Graph 55). After 269 feet *Favias*, etc., become larger and more varied (Graph 52), being represented by *Goniastrea pectinata*, *F. favius*, *G. retiformis* (1–6 inches), *Goniastrea* K.18 * and in addition one *Pocillopora bulbosa*. As the reef slopes down to datum level large colonies of *A. pulchra* are found forming bush-like growths, their tops rising to about 2 feet above datum (see Graph 60, and level section). No other Acropores are present.

Acyonaria appear on the Inshore reef, but reach their maximum abundance just beyond it (Graph 44). *Xenia* is seen first, growing in gaps between the coral platforms where pools of water lie except at lowest tides. Beyond 270 feet *Sinularia polydactyla* covers areas up to 18 inches across, large *Sarcophyton trocheliophorum* and *S. glaucum* are frequent, and a few *Lobophytum crassum* occur.

(4) *The Seaward Slope. 302–500 feet. 0–5·2 feet below datum.*

The slope descends at a gradient of about 1 in 52, its seaward edge dropping more steeply to the flat sandy floor of the anchorage. The slope is mainly covered by extensive patches of loose coral rock, very uneven and full of holes and caverns. Larger gaps between these rocks form sandy pools which may be partially overgrown by corals projecting into them from the rocks. Three such pools are crossed by the traverse, (1) from 304 to 334 feet, (2) from 354 to 362 feet, and (3) from 406 to 430 feet, the bottom levels in the three being 0·8, 1·4 and 2·4 feet below datum respectively.

Algae are few from the first, and apart from microphytic forms on the rocks, rapidly become absent along the traverse. Up to 347 feet *Galaxaura lapidescens*, *Gracilaria Textorii*, *Roschera glomerulata*, *Bornetella nitida*, species of *Dictyosphaeria*, *Halimeda Opuntia* and *H. macroloba* are present (Graphs 41 and 46).

Filamentous diatoms are present everywhere, forming large tufts on the rocks and corals.

Coral growth over the Seaward Slope is rich, and increases in numbers and variety up to the limit of the reef. The abundance of bare irregular coral rocks which project upwards to just above datum level now restricts most of the living coral to the sides and crevices of the rocks and to the tops of rocks situated well below datum level. The higher rocks are either bare, or covered by encrusting and other corals which have been partially or completely killed at times, and have recolonized these situations while conditions remained favourable. Plate XI, *b* shows a map of part of the traverse at about 366 feet. Rocks rise from pool 2 (see above) to about datum level, or just above it, and are very richly covered by living coral.

* This coral could not be satisfactorily determined, and is so labelled in the collection deposited in the British Museum.

From 302 to 364 feet the corals are composed of forms found already on the Inshore Part of the Reef and in the Western Moat, but with a greater number of species of *Acropora* (see Graph 58). Corals are mainly represented by *Montipora ramosa* (Graph 50), *M. foliosa*, species of *Favia* (Graphs 52 and 55), and Acropores. *M. ramosa* forms fairly extensive platforms over the higher rocks, but much is dead and is then covered in part by *Alcyonaria*. Unlike the Acropores, *M. ramosa* does not spread into the deeper pools. Beyond 364 feet the rocks are very thickly covered by living coral (see Plate XI, *b*). *M. ramosa* is absent, but Acropores and encrusting species of *Montipora* abound, and may be of more brittle build than those nearer the shore. New genera make their appearance, while species of *Favia* are fewer and smaller.

Species of *Favia*, *Goniastrea*, etc., are most abundant up to 360 feet, and grow on the ledges, vertical faces and hollows of the rocks. They are almost as numerous as on the Seaward Slope of Traverse I, and the relative frequency of occurrence of the species is much as it is on the shallower parts of the latter situation. Species found in the deeper parts of Traverse I do not occur. Table IV gives the species present together with notes on their distribution.

TABLE IV.—*Species of Favia, Leptastrea, Goniastrea and Coeloria on the Seaward Slope of Traverse II.*

Species.	Diameter of colonies in inches.	Numbers of colonies.		Remarks.
		302-364 ft.	364-500 ft.	
<i>Leptastrea roissyana</i> . . .	3-4 .	2 .	1 .	Occurs here and on the inshore part of the reef, as it does on the reef flat and Seaward Slope of Traverse I.
<i>Goniastrea retiformis</i> . . .	2-10 .	16 .	8 .	The largest and most numerous species, as on the Seaward Slope of Traverse I.
<i>Favia abdita</i> . . .	3-7 .	6 .	2 .	} Frequent, as on Seaward Slope of Traverse I.
<i>Favia astraeiformis</i> . . .	2-6 .	7 .	1 .	
<i>Favia favius</i> . . .	2-6 .	4 .	6 .	..
<i>Goniastrea K. 5*</i> . . .	4-6 .	4 .	0 .	Frequent, as on Seaward Slope of Traverse I.
<i>Favia halicora</i> . . .	2-6 .	12 .	0 .	More frequent than on Seaward Slope of Traverse I.
<i>Favia doreyensis</i> . . .	2-8 .	5 .	1 .	Frequent, as on Seaward Slope of Traverse I.
<i>Coeloria</i> sp. . . .	2-5 .	1 .	5 .	..
<i>Goniastrea solida</i> . . .	3 .	0 .	1 .	..

Goniastrea pectinata, present of the inshore part of the reef and on the reef flat of Traverse I, is here absent, as on the Seaward Slope of Traverse I.

* This species could not be satisfactorily determined, and is so labelled in the collection deposited in the British Museum.

Montipora foliosa and *M. erythraea* become increasingly frequent up to 430 feet (Graph 55), the colonies covering areas up to 24 inches across. They appear in all situations, but chiefly as a horizontal covering of the higher rocks, from which turret-like and foliose projections grow where space permits.

The Acropores are abundant in both species and colonies, forming a few high platforms which are partly dead, and bush- and bracket-like growths projecting into the pools.

Table V shows the species and colonies present, and the distribution of some of them is shown in Graphs 58–65, for comparison with Traverse I (Graphs 30–35). *Acropora hebes* is almost restricted to the inshore part of the reef (Graph 59); it also characterizes the higher parts of the Seaward Slope of Traverse I. *Acropora pulchra* (Graph 60) is characteristic of parts of the traverse just above datum which are directly open to deeper water; and *Acropora rosaria* (Graph 65) is present in the deeper parts much as on Traverse I. No marked zoning in the distribution of other Acropores is perceptible, possibly owing to the gentle slope of this region, and the abundance of rock near the surface of the sea.

TABLE V.—*Species of Acropora present on the Seaward Slope of Traverse II.*

Species.	Diameter of colonies in inches.	Numbers of colonies.		Remarks.
		302–364 ft.	364–500 ft.	
<i>A. hebes</i>	..	7 sq. ft.	0	Almost restricted to the inshore part of the Reef.
<i>A. pulchra</i>	..	7 sq. ft.	0	Grows on rocks in the middle of Pool 1, but does not appear again.
<i>A. gemmifera</i>	..	2 sq. ft., 1 colony	4 sq. ft. 2 (colonies 6 inches)	Not abundant, but fairly frequent in the shallower parts and on the higher rocks.
<i>A. polymorpha</i>	..	1 sq. ft.	31 sq. ft., 9 (colonies 6–14 inches)	..
<i>A. delicatula</i>	3–18	4 colonies	18 colonies	..
<i>A. formosa</i>	2–8	3 „	5 „	..
<i>A. quelchi</i>	2–15	3 „	44 „	..
<i>A. squamosa</i>	3–18	1 „	17 „	..
<i>A. rosaria</i>	3–12	1 „	6 „	..
<i>A. exilis</i>	3–24	0 „	70 „	Particularly abundant at the seaward edge of the reef.
<i>A. loripes</i>	3–7	0 „	5 „	..

Massive *Porites*, previously appearing but once, becomes more frequent (Graph 51), but the colonies are small in size (1–7 inches).

As on the Inshore Part of the Reef, a few small *Pocillopora bulbosa* and *Cyphastrea* occur, but not beyond 376 feet (Graphs 53 and 54). *Galaxea* of increasing size (<10 inches) and numbers and *Symphyllia* are most frequent on the landward part of the Seaward Slope, and one *Coeloria* is present (Graphs 56 and 57). Beyond 364 feet *Seriatopora hystrix*, massive *Porites* sps. and *Fungia* (Graphs 68, 51 and 71) appear. The latter become numerous on the edge of the reef lying among the rocks and covered by undisturbed water. *Stylophora pistillata*, *Lobophyllia*, *Heliopora* (Graphs 66, 67 and 70), *Psammocora exesa*, of a massive growth form, *Echinopora lamellosa*, another coarser species of *Echinopora* and *Platygyra phrygia* occur infrequently, and outside the traverse an occasional *Goniastrea* and *Turbinaria* occur (see Plate XI, b).

The seaward edge of the reef is characterized here by an extensive and fragile growth of *Acropora exilis*, *A. rosaria*, and by large and delicate expansions of *Montipora foliosa*, together with abundant *Fungia* extending down to the sandy bottom beyond the reef (Graphs 63, 65, 55 and 71). On either side of the traverse living corals of the reef edge project upwards and outwards, forming an almost vertical wall composed of *Acropora hyacinthus*, *A. rosaria* and *A. exilis*, with occasional large bush-like colonies of *Heliopora*.

The flat sandy bottom beyond the reef edge from 480 to 500 feet is almost devoid of corals, two small colonies of *A. exilis* and a few of *A. polymorpha* being attached to rocks in the sand.

Alcyonaria (Graph 44) become larger and more abundant on the Seaward Slope of Luana reef than on any other part of Low Isles. They flourish most in the shallower pools near the level inshore part of the reef and on rock surfaces which are usually just submerged. The richest alcyonarian pools lie to one side of the traverse, and a portion of such a pool is mapped in Plate XIII. Further out the alcyonaria may be very large, although not so numerous, and occur mainly on the rocks just below datum.

Xenia, present on the Inshore Part of the Reef, only occurs again as small colonies in pool I between 302 and 312 feet. *Nephtya mollis* is found in abundance at about 314 feet growing on dead coral, and covers one square yard of debris on the sand beyond the reef edge. *Clavularia inflata* var. *luzoniana* appears on the traverse at the edge of the reef, covering 8 square feet between 444 and 455 feet, but is also found in the richest alcyonarian pools to one side of the traverse. Other Alcyonaria present are shown in Table VI. The most frequent are *Sarcophyton trocheliophorum* and *S. glaucum*, often very large; and usually growing in positions which just expose the colonies at low spring tide, and *Alcyonium pachyclados*, occurring abundantly as small isolated colonies 1-6 inches across or in extensive masses 2 feet across.

TABLE VI.—*Alcyonaria, other than Xenia, Nephtya and Clavularia, present on the Seaward Slope of Traverse II.*

Species.	Diameter of colonies in inches.	Numbers of colonies.
<i>Alcyonium pachyclados</i> . . .	4-24	34
<i>Sarcophyton trocheliophorum</i> . . .	2-30	13
<i>Sinularia polydactyla</i> . . .	4-18	14
<i>Lobophytum crassum</i> . . .	4-9	4
<i>Lobophytum pauciflorum</i> var. <i>validum</i>	4-28	3
<i>Sinularia lochmodes</i> . . .	3	1

Other Alcyonaria not encountered on the traverse but present just outside it are *Sinularia flexibilis* and other species (see Plate XIII). These and *Clavularia inflata* var. *luzoniana* are not exposed at low spring tides, whereas *Sarcophyton trocheliophorum*, *Sinularia polydactyla*, *Lobophytum crassum*, *Lithophytum arboreum* and *Xenia* may be completely exposed.

The Zoanthid *Palythoa* is found on the most exposed rocks of the traverse beyond 400 feet, 5 colonies (<10 inches) being present.

On Plate XIII are mapped two areas in the rich alcyonarian zone on the lee side of the reef near Traverse II. The bottom lies at about 1 foot below datum. A few sandy pools lie in this region, as seen in Map A, but where the substratum is rocky, alcyonarian growth may be almost continuous, as seen on the left side of Map A. This region may be compared with the rich coral zones on the seaward slope (1) at 2 feet below datum on Traverse I (Plate XI, b), and (2) at 1.4 feet below datum on Traverse II (Plate XI, b).

THE SURVEY OF TRAVERSE III.

The position of this Traverse is seen in Text-fig. 1, and it is shortly referred to in Vol. III, No. 2, p. 64 of these reports. It passes from the outer rampart over the windward edge of the reef in line with the lighthouse and E. beacon in a south-easterly direction. A level section along this traverse is given, the vertical and horizontal scales being the same as used for the seaward slopes of traverses I and II, so that direct comparisons may be made. It is apparent that this windward side of the reef descends in a short distance to a much greater depth than does the leeward side. The former drops to 86 feet below datum at 1155 feet from the crest of the outer rampart, while the latter at 850 feet from the crest of the boulder tract becomes nearly level at a depth of 36 feet (see level section of Traverse I and Text-fig. 1). The Seaward Slope of Traverse III at first descends with about the same steepness as on the leeward side (Traverse I), but it continues so for a greater distance until a depth of 20 feet below datum is reached at 877 feet. Here the reef drops almost precipitously to a depth of 48 feet at 945 feet, and then less steeply down to 86 feet. Beyond this deep the sea floor shoals to 78 feet below datum. The traverse first crosses the inner rampart, composed of "honeycomb" rock (0-74 feet), and then passes over the outer rampart covered by shingle (74-298 feet). Honeycomb rock then becomes exposed, as shown in the map (Text-fig. 1), and continues to about 580 feet. Small boulders rise 2-4 feet from the general level, which further out is composed of rocks and sandy patches. Sand continues beyond 680 feet. From 867 feet outwards the nature of the substratum could not be observed from a boat. No mud is present here in the shallow water as occurs on the lee side of the reef (Traverse I). A detailed survey of the organisms living along this traverse would be desirable for comparison with those on Traverses I and II on the leeward side; however, owing to lack of available time and calm weather which would permit the use of a diving helmet, such a survey was impossible. By means of a boat and water telescope the dominant organisms were noted on the traverse down to about 16 feet below datum. For this purpose the upper part of the seaward slope was divided into four 100-foot regions, and the organisms occurring on each are recorded below the level section (Plate VIII). As would be expected, algae only occur on the upper part of the slope just below datum, and are few in numbers and species, as on the other seaward slopes of Low Isles.

The corals form a luxuriantly growing belt which extends into much deeper water than on the lee side of the reef. At a depth of 16 feet and below, as far as could be seen from a boat, *Montiporas* and *Acroporas* abound, forming huge colonies, whereas on Traverse I corals had become very few at this depth, and were absent at 18 feet where the muddy lagoon floor was reached.

The corals occurring on the first 100 feet of the Seaward Slope (see level section) resemble those present on the leeward side of the reef (see Seaward Slope, Traverse I), with the addition of large and small massive species of *Pocillopora* (*P. verrucosa* and *P. eydouxi*) and *Acropora decipiens*. These corals do not occur elsewhere on Low Isles, and are characteristic of the exposed outer ridge and reef crest of outer barrier reefs such as Yonge Reef.

On the second 100 feet of the traverse where small boulders rise to low-water level many corals seen on the previous section persist, such as *A. squamosa*, *G. retiformis*, *F. doreyensis*, *Millepora*, etc., but others which characterize shallow water elsewhere on

Low Isles do not occur again, such as *F. abdita*, *F. halicora*, *Hydnophora*, *Platygyra*, *Pocillopora bulbosa*, etc. The Outer Barrier Reef forms noted above continue, and to them are added others such as *A. abrotanoides*, a coarse growth form of *A. gemmifera* (also seen on Yonge Reef), and *A. hyacinthus* and others of that type.

On the third 100 feet of the slope the shallow-water *Favias* and *Pocilloporas* are absent. The deeper-water *Favias* of Traverse I continue or appear for the first time, such as *F. clouei*, *F. vasta* and *F. favius*. Deeper-water forms found also on the lee side appear, such as *P. danae*, *Stylophora*, *Lobophyllia*, *Seriatopora* and *Heliopora*, make their appearance. Of the outer barrier reef "Outer Ridge" forms, *A. decipiens*, *A. gemmifera*, *A. abrotanoides* and *Pocillopora eydouxi* do not continue into this deeper water. *Millepora* forms very large branching colonies and *Montiporas* give huge fan and bracket-like growths.

On the fourth 100 feet the *Acroporas* are luxuriant and mostly resemble outer barrier reef types. *A. polymorpha* shows many coarse growth forms, and *A. hyacinthus*, etc., occur as large flat or dish-like brackets. Stag-horn types become very large and tree-like. Other corals identifiable from a boat are luxuriant, such as large *Montiporas*, branching *Millepora*, and *Favia favius* and *Leptastrea ehrenbergana*. This list is not to be considered in any way exhaustive, but it represents the larger and more conspicuous forms.

Beyond 860 feet the corals on the Seaward Slope could not be identified from a boat, and the record thus ends.

DISCUSSION AND CONCLUSIONS.

Some of the points of interest arising out of the surveys may now be considered.

Algae occur in abundance only along parts of Traverse I, and are almost absent on the Seaward Slopes of all three traverses. In the Western Moat and on the Inshore Part of Traverse II the abundance of algal species is approximately inversely proportional to the numbers of species of corals. All the major groups of algae are at a maximum in the shallower part of the Moat, where temperature and other extremes are greatest. They are fewer on the reef flat and are practically absent outside the Boulder Tract, even where corals are scarce and the water shallow. They decrease in numbers towards the drying flat and in the deeper water of the Moat.

The limiting factors for this algal distribution are not readily apparent, although corals are doubtless absent from the shallower parts of the Moat owing to the extremes of the physical conditions. The shallower Moat differs from its deeper parts in the wider extremes of temperature and salinity, while the oxygen content may remain stationary, or even fall at the end of a low-tide period instead of increasing to supersaturation. The pH rises during the day in all parts of the Moat, but CO₂ does not appear to be a limiting factor for plant growth. Possibly nutrient salts are of more importance. Phosphate determinations by Orr indicate that decomposition takes place in the reef flat sand at a short distance below the surface. Undisturbed sand contains an appreciable quantity of soluble phosphates, but Moat sand, which is being continually moved about and washed, contains little. At low tide the deeper Moat water seldom contains recognizable traces of phosphates. However, corals are able to utilize phosphates (Yonge, Vol. I, No. 6, p. 150), and presumably other salts, directly from the water both during the day and

night, so that less phosphates, etc., must be available for algae in the deeper Moat where corals grow.

The brown algae are fewer than the reds and greens, and the green algae comprise most of the widely distributed species, which extend to all parts of the Moat and Boulder Tract. On the Dry Tortugas, Taylor finds a somewhat similar type of algal distribution. In the moat of Garden Key the stagnant water covers a flora mainly composed of red and green algae: while the bathymetric distribution of algae shows that the reds, browns and greens all decrease below 3 metres, but the greens become dominant in deeper water (70–90 metres). Taylor considers the distribution to be primarily dependant upon light, and the red algae in deeper water to be inhibited by the soft character of the bottom. On Low Isles along Traverse I light cannot be the main factor in the distribution of red, brown and green algae, since all parts of the Moat and the upper part of the Seaward Slope are well illuminated; neither can the soft mud on the Seaward Slope be responsible for the absence of algae here, since mud is only present in the deeper parts.

The different positions of maximum growth of the more important algae can be compared in graphs 6–15. Most species show a gradual rise and fall about their maxima, but *Anadyomene Brownii* and *Sargassum* suddenly reach their maxima in the shallower water and gradually fall off in the deeper Moat (Graphs 6 and 8), while *Turbinaria* (Graph 10) shows the inverse type of distribution, gradually rising to a maximum as the Moat deepens and then suddenly falling off before reaching the deepest parts.

The distribution of corals along the traverses is not likely to be influenced by the supply of plankton and the variations in oxygen content, the pH and the excess base of the water. It probably depends principally upon factors such as the levels of the substratum relative to that of low water, the ranges of temperature, salinity, etc., of the water, and the nature and amount of sediments which are deposited and which may lie undisturbed on the rocks and corals.

The maximum coral growth (Graph 3) occurs in the deeper parts of the Moat, and on the Seaward Slope of Traverse I at about 2 feet below datum. (The possible cause of the reduction of corals below this level here will be considered below.) The greater part of the reef along Traverse II is little more than 2 feet below datum, and corals steadily increase in numbers to the reef edge (Graph 43); the rise in numbers of corals beyond 416 feet at the seaward edge, where the depth is at first little increased, perhaps may be associated with the more direct exposure of this region to open water at extreme low tides. On Traverse III coral growth continues luxuriantly below 16 feet.

The level of the zones bearing the greatest numbers of species and of colonies coincide on both Traverses I and II (Graphs 2, 3, 42 and 43). On the fringing reef off the windward side of Maer Island and on the Aua reef, Tutuila, Mayor found the greatest number of coral species close behind the outer edge of the reef, while the maximum numbers of colonies occurred some distance from the edge (400 feet on Maer Island). It must be remembered that these reefs contrast in form and position with Low Isles, and the coral bearing surface of their flats is very much wider than any of the rich coral zones traversed by the Low Isles survey.

The upper limit of coral growth is determined in the first place by the range of water level. In the Moat the height of the branched and massive coral platforms appears to be controlled by the permanent level of low water, and lies at 0.3 and 0.15 feet respectively above the latter. Outside the Boulder Tract and rampart coral growth starts at a lower

level, just above datum (see Traverses I and III), so that corals are only exposed to the air intermittently at exceptionally low tides. No platforms are here formed with flat dead or living tops at a constant level since the water is continually changing, but over the level inshore part of Traverse II coral growth, except for *Acropora hebes*, is checked above 1.6 feet above datum (see level sections).

Massive corals with flat dead tops have been noted in other regions by Darwin, Semper and Wood Jones. The cause of the dead tops has been ascribed by Darwin and Semper to tide level and consequent exposure to air, sun and rain, while Wood Jones considers that on Cocos Keeling atoll the majority of cases are due to the deposition and accumulation of sediment in amounts greater than can be removed by normal agencies. The distribution of such dead-topped corals on the traverses and on Low Isles generally, where they are found abundantly in Moats but rarely outside the Boulder Tract, even in regions where sediment is the limiting factor, and the direct correlation of the height of such colonies with low-water level, indicates that here water level and not sediment is the main factor responsible for such growth forms on Low Isles.

The distribution of various corals is clearly influenced by their several abilities to withstand heat and silt. Thus *Acroporas* which easily succumb to silt and heat (Mayer, 1924) occur mainly on the upper parts of the Seaward Slope of Traverse I and over a large part of Traverse III, but are infrequent in the Moat and absent in muddy zones such as the deeper parts of Traverse I; while massive *Porites*, well able to withstand silt and heat (Mayer, 1924), is present at all levels on the traverses wherever there is water (Graphs 19, 51, 30 and 58).

The Moat provides the greatest extremes of temperature, exposure, etc., on the reef. During the summer, high temperatures may cause a considerable mortality, and the winter night minimum may be too cool for reef corals, which are injured by a temperature below about 18.5° C. (Mayer, 1924). The presence of rich coral growth in the Moat may be made possible by the occurrence of semi-diurnal tides, which gives a maximum exposure of only 5½ hours. Movement of sediment is considerable in the Moat, but corals here are well able to remove the coarse sandy sediment from their surfaces by their own activity and by the aid of water movements. The dominant Moat coral is *Montipora ramosa* (Graph 16), and it is restricted to this type of region. In the shallow moats of similar form on the reefs in the Bay of Batavia *M. ramosa* may be almost the only coral present, and even this may be absent if there is no cooling circulation of water through the moat. The temperatures here are not more extreme, but the moats may be exposed for 12 hours as there is only a single tide a day.

Among the Moat corals some appear extremely resistant to exposure or to a wide range of conditions. *Pocillopora bulbosa* (Graph 25) occurs in the Western Moat and through most of the Seaward Slope of Traverse I. Massive *Porites* has been mentioned above, and among the species of *Favia*, etc., *Goniastrea pectinata* and *Leptastrea roissyana* are the only corals other than massive *Porites* which can live in the shallow as well as the deeper parts of the Moat. *Leptastrea roissyana* (Graph 21) occurs throughout the Seaward Slope also, and is almost as successful as massive *Porites* in living under a wide range of conditions. Others appear to thrive in the deeper part only of the Moat, and grow equally well on the shallower part of the Seaward Slope; such are *Cyphastrea* and many species of *Favia* (Graphs 20 and 26). Corals such as *Acropora*, *Galaxea*, *Symphyllia* and *Montipora foliosa* in the Moat are restricted to the deeper parts and reach their

maximum growth on the Seaward Slopes (Graphs 30, 29 and 28); they usually do not live in the more exposed moats of the reefs in the Bay of Batavia.

On Traverse II the gentle slope of the Inshore Part of the Reef results in conditions prevailing for part of the year which approach those of the Western Moat to a certain extent. A resemblance between the corals and algae of the two regions is present, although the Moat lies at 1·8–2·4 feet with its *M. ramosa* platform at 2·8 feet above datum, while the Inshore Part of the reef on Traverse II lies at 0·8–1·2 feet, with its *M. ramosa* platform at 1·6 feet above datum. Differences between the two regions, however, exist. On Traverse II all the *M. ramosa* is living, massive *Porites* is scarce and *Psammocora* absent (Graphs 50 and 51). The algae, although various (Graphs 46–49), are far less abundant, the phanerogams almost absent (Graph 45), and filamentous diatoms are much more abundant than in the Western Moat.

For details of the effects of various types of sediment on corals on Low Isles, reference should be made to Marshall and Orr, Vol. I, No. 5 of these reports. Corals can remove considerable quantities of coarse sand and fine mud which may fall upon them, either by muscular or ciliary activity, or by entangling the finest mud in mucus, which is then swept away. In the removal of sediment corals may be aided considerably by water currents. The ability of different species to remove sediment varies, but usually sediment does not appear to be directly harmful to growing corals unless they are actually buried by it.

Some of the effects of sediment can clearly be seen by a comparison of the three traverses. On the Seaward Slopes the reduced range of temperature and the constant circulation of water of nearly uniform composition permits the growth of a much richer coral fauna than elsewhere. Forms appearing exceptionally in the Moat here reach a maximum and many new types occur. Coral growth on Traverse I, however, is strongly inhibited at a small distance below datum, although light, food, range of temperature and free circulation of water can hardly be very different at so slight a depth. Yet on other reefs coral growth is luxuriant down to several fathoms, and on Traverse III across the windward edge corals are luxuriant far below 16 feet. The limiting factor on the leeward edge appears to be mainly the deposition of fine grey mud, which lies undisturbed on all surfaces in increasing thickness down the Seaward Slope. Mud is found in appreciable thickness from about 4 feet below datum on Traverse I, and corals diminish here in numbers and size directly as the mud increases (see level section and Graph 3). On the windward side of Low Isles the rocks are clean as far down as could be seen from a boat, and coral growth persists into deeper water.

The fine grey sediment on the leeward side appears to be more harmful than the coarse sandy sediment falling in the Moat, but the exact nature of its effects upon growing coral is not clear. Since the sediment lies thickly on exposed rocks, corals must be dependent mainly upon their own activity rather than on water currents for its removal. Small corals may here be liable to be smothered by muddy sediment, which is much more easily shifted by water currents than is sand, but once it has covered the coral, is not more easily removed by the coral itself. The smothering of a coral by mud, when this takes place, appears to act by removal of aerated water, which leads to suffocation. The fine sediment does not itself appear to be necessarily poisonous. The deleterious effect of grey mud has been pointed out in other regions by Gardiner (1930, pp. 4–9).

It has been shown (Marshall and Orr) that large-polyped corals can deal with sediment

falling from above more effectively than some of the small-polyped forms. Thus *Fungia*, *Galaxea*, *Symphyllia* and *Goniastrea pectinata* all readily remove large amounts of mud and sand falling on them, while massive *Porites* only removes mud easily, and *Psammocora* is unable to remove much fine sediment. It is noteworthy that on Traverse I *Psammocora* does not appear on the Seaward Slope, where mud lies on the rocks, but is present on clean vertical faces of coral heads (Plate XII) outside the Traverse; and that as the deeper muddier regions are reached, the majority of corals able to withstand these conditions have large polyps. The deeper water *Favia vasta*, *F. clouei*, *Astreopora* and *Lobophyllia* have larger polyps than the species found in shallow water. Massive *Porites*, however, according to Marshall and Orr appears to be least efficient at removing sediment, especially if it is coarse, yet it is found all along the Traverse, and its surface is clean down to the muddiest regions where corals grow.

The associations of corals on the Seaward Slope of the lee side of the reef are roughly of three types. In the shallower water, where the deleterious influence of the mud is not felt, Acroporas are dominant, and *Favia*, *Symphyllia* and *Cyphastrea* are numerous (Graphs 30, 20, 28 and 26). Some of the acroporas show a zoning correlated with depth (Graphs 31-35). Throughout the rest of the Seaward Slope where the influence of the mud begins, many *Favia*, *Pocillopora*, *Montipora*, *Galaxea*, *Stylophora*, *Astreopora* and *Lobophyllia* occur (Graphs 20, 25, 27, 36, 38 and 37). In deeper muddier regions only a few *Stylophora*, *Lobophyllia*, *Astreopora*, *Favia clouei*, *F. vasta*, *F. favus* and branching *Porites* can live besides the widely distributed massive *Porites*.

A zoning of the corals on the Seaward Slope of Traverse II is less marked than on Traverse I, as a depth of only 5.2 feet below datum is reached and mud is not present. The most marked zoning is that of the acroporas in shallow water, which resembles that on Traverse I. The gentle slope here allows the abundant growth of *Acropora pulchra* (Graph 60) at 0-0.4 feet above datum, which only appears at this level occasionally on the steeper parts of the N.W. side of Low Isles. The abundance of Fungidae (Graph 71) on the Seaward part of Traverse II may be correlated with the comparatively undisturbed water. They are absent from the outer parts of Traverse I, but are present in the quiet water of the Fungia Moat. Species of *Favia* (Graph 52), on the other hand, are less numerous than on Traverse I (Graph 20), where they appear to withstand more mud than the acroporas, and thus can extend further seawards. On Traverse II the numbers of *Favia* and *Acropora* colonies are roughly inversely proportional (Graphs 52 and 58), and on the outer half of the Seaward Slope where the acroporas are abundant the *Favias* are few or absent.

The fauna of the Seaward Slope of Traverse III presents several noteworthy features. It does not include corals which characterize the moats, but which also occur in small numbers on the Seaward Slopes of the lee side of the reef, such as *Leptastrea roissyana*. It comprises very many forms characteristic of the other Seaward Slopes, such as those recorded for Traverse I; and in the deeper parts of Traverse III stag-horn types are found such as also grow in the Anchorage of Low Isles, and in the Anchorage Coral Zone on the lee side of Outer Barrier Reefs. On this exposed windward corner of Low Isles is found the nearest approach to the conditions prevailing on the Outer Barrier Reefs, and it is here only on Low Isles that many corals are found which characterize the outer parts and crests of such reefs. The most noteworthy forms are Acroporas such as *A. abrotanoides* and *A. decipiens*, and other species which occur elsewhere but here show stout

and coarse growth forms such as *A. gemmifera* and *A. polymorpha*. These are all very resistant to wave action. In deeper water below 16 feet the huge stag-horn growths of *Acropora* and the fans of *Montipora* occur also in the deeper parts of the Low Isles Anchorage and on the less exposed parts of Outer Barrier Reefs at similar or greater depths.

There is little indication as to how far distribution of corals may be influenced by competition between species for the available space. Mayor (1918) has suggested that such competition takes place on parts of the reef flat of Maer Island. On Traverse I, only in the *Acropora* zone of the Seaward Slope are corals so closely packed that the rocks are completely covered, and it is unlikely that where quick growing and extensive *Acroporas* are present other corals can easily become established in quantity. On Traverse II the distribution of *Favia* and *Acropora* may perhaps be taken as an example of effective competition between corals for the available space, *Acropora* crowding out the *Favia*. The sides of rocks and more low-lying sites for coral growth on the Seaward Slope are so densely clothed by coral that considerable competition between species must exist. However the tops of the rocks about datum level are regions where successful coral growth is determined by ability of the corals to withstand the limiting factors of both normal and exceptional physical conditions. On a narrow reef such as this, regions can be recognized where coral distribution is effected mainly by (1) direct reaction to the physical environment, or (2) competition between species, but the regions are not widely separated as Mayor describes on the fringing reefs of Tutuila and Maer Island.

Traverse II may be compared in its position with the short account by Hedley and Taylor (1907) of a traverse across the lee side of East Hope Isle, another "island reef" situated some 40 miles north of Low Isles. Here the living reef 40 feet wide is narrower and far less rich in varieties of coral. The edge of the reef is dominated by *Goniastrea* and *Porites*, with more delicate *Acropores* between them. Behind lies a zone of *Turbinaria*, *Coeloria*, *Fungia*, *Galaxea*, *Herpetolitha* and *Acropora*, and then two zones follow between the living coral and the sand cay; these are 100 and 200 yards wide and dominated by *Alcyonaria* and algae respectively. The *Alcyonarian* zone is far more extensive and luxurious than on Low Isles, *Sarcophyton* reaching 8 feet across. No level area dominated by *M. ramosa* occurs. The algal zone, which is richer than on Traverse II, extends from that of the *Alcyonaria* to the beach. Details of levels along this traverse are not given.

On the traverse across a New Hebrides fringing reef, Baker (1925) describes an area largely covered by *M. ramosa* lying near the shore as on Traverse II. The level of this region is not given, but it appears to lie between 0 and 2.6 feet below datum. If this is so, then it is considerably lower than the Inshore Part of Traverse II, which is dominated by *M. ramosa*.

II. DESCRIPTION OF SMALL AREAS ILLUSTRATING THE CORAL FAUNA ON CHARACTERISTIC ZONES OF AN OUTER BARRIER REEF (YONGE REEF)

The several types of Island, Inner and Outer reefs occurring off the coast of Queensland have been described by Spender (1930), and their mutual differences noted. Ecological features of Island Reefs have been considered in the preceding section and in Vol. III, No. 2, and by Spender, 1930. Of the Outer reefs which we visited there was

reason to consider Yonge Reef to be an example showing very completely the basic type of Outer Barrier Reef (Spender, 1930, p. 31).

Plates XIV–XVI show large-scale maps of typical areas on an Outer Barrier Reef (Yonge Reef). Reference should be made to Mr. Spender's description, 'Geographical Journal', Vol. LXXVI, p. 32, and to Vol. III, No. 2, Text-fig. 5, and Plate XVII, fig. 2 of these reports, which illustrate the main features of an Outer Barrier Reef. No detailed quantitative work was done on the coral fauna of an Outer Barrier Reef; and as the data referring to such reefs is not presented together in any one part of these reports, the record of coral fauna on selected areas of an Outer Barrier Reef is included here, so that ready comparison may be made with the records of selected areas on Low Isles. The Pacific "Outer Ridge" could not be mapped owing to water conditions. The areas chosen lie on the "Reef Crest", the "Outer Moat", the "Anchorage Coral Zone" and the "Zone of Coral Heads".

The differences in physical conditions prevailing on Outer Barrier Reefs and Island Reefs are chiefly two, those of level, and of water composition and movements. The low level of outer reefs compared with other types of reefs off the Queensland coast has been discussed by Spender, 1930, p. 35, and a consideration of weather and water conditions and their biological significance around barrier reefs has been given by Orr, Vol. II, No. 3 of these reports, together with a comparison of conditions in other localities in the barrier reef region (pp. 60 and 66).

REEF CREST.

Plate XIV shows a small area on the Reef Crest, which extends over 3 miles in length and 100 yards in breadth, and forms the highest part of the reef. The reef crest is shortly described in Vol. III, No. 2, pp. 32 and 84, Text-fig. 5, and Plates XVII, fig. 2, and XXIII, figs. 1, 3 and 4, and by Spender, 1930, p. 83.

Much of the reef crest bears less living coral than this particular patch. A smooth and very hard substratum is formed by coral rock covered by a veneer of nullipores. None of the corals project far above the surface, and they are few in both numbers and species, leaving extensive areas of bare rock (compare Plates IX, XI and XIII, where little rock is not covered by corals).

The Acropores tend to show a pedestal-like growth, the upper fan or bush of branches being separated from the substratum by a narrow and solid "stem". This growth form is not apparent when viewed from above in the map. The acropores are also all strongly built, *A. gemmifera* (species 6 on map) showing a stouter growth form than occurs on Low Isles in sheltered water. *Tubipora* is a conspicuous feature of this area; the pink *Pocillopora verrucosa* is frequent; knob-like and encrusting corals are fairly numerous (*Millepora*, *Montipora*, etc.), but together with the *Favias*, are small in size. A grey Zoanthid and the sponge *Phyllospongia ridleyi* are characteristic features, and the bright green alga *Chlorodesmis comosa* and the starfish *Linkia guildingii* are conspicuous. Little dead material is present here, but may be more abundant in other parts. No loose debris lies on the surface of this high smooth rock.

The number of coral genera is small, and except for *Tubipora*, they represent types of very general occurrence on all types of reef. Of the 9 species of *Favia* (and allied genera), 3 occur also on the upper parts of the Seaward Slopes of both windward and

leeward sides of Low Isles, on the sides of coral heads, and in Moats of Low Isles (*Goniastrea retiformis*, *Favia abdita* and *Coeloria* sp.). They are thus able to exist under very variable conditions. Three others occur also on both the Seaward Slopes and on coral heads on Low Isles, but not in the moats (*Goniastrea* K. 5, *Leptastrea ehrenbergana*, *Favia clouei*), and can thus live in varied conditions, but the extremes prevailing in Moats appear to be more severe than on the Yonge Reef Crest. Of the remaining three species (*Favia laxa*, *F. waykayana* and one undetermined sp.), only one is recorded from Low Isles, and that from the side of a coral head, and they thus appear to favour more open water.

The Acropores present on the Reef Crest are also found on both Seaward Slopes of Low Isles, with the exception of *A. pulchra* and *A. rosaria*. It is noteworthy that *A. hebes*, occurring on Low Isles at higher levels than other acropores, is here found on the highest part of the reef.

OUTER MOAT.

Plate XV shows two areas in the Outer Moat region. This zone (see Vol. III, No. 2, pp. 32 and 83, and Spender, 1930, p. 32) is about 100 yards wide and lies between the reef crest and the outer ridge at the Pacific edge. It lies at a lower level than both Reef Crest and Outer Ridge, and is usually filled with water even at low tide, but the water is agitated and not still as in the Low Isles moats. The rock is heavily encrusted with nullipores, its surface is smooth and devoid of debris and loose material. Corals here are both varied and luxuriant, but do not project vertically to any great extent. Many more genera are present than on Low Isles moats (compare Plates IX and X), and many of the species here are distinct from those occurring on Low Isles.

Conspicuous corals seen on the map are the wide dish-like expansions of *Acropora hyacinthus*, etc. (12 on the map), the encrusting and knob-like upgrowths of *A. palifera*, coarse low-lying branches of *A. decipiens* (upper area), very stout colonies of *A. gemmifera* (6 on map), and small finely branching colonies of *A. delicatula* (13, lower area). The coarsely branching *Pocillopora verrucosa* grows larger than on the reef crest, while the very large *Pocillopora eydouxi* forms solid pink masses several feet long (lower area). Massive corals cover less area than do the branched ones (compare reef crest where massive corals are more numerous), but they may be very large in size (ex. *Coeloria*, upper area) and are usually without dead tops. The genera of massive form are very varied, being represented by *Coeloria*, *Platygyra*, *Hydnophora*, *Favia*, *Leptastrea*, *Goniastrea*, *Porites*, etc. No loose corals occur, such as *Fungia*. A few Alcyonaria are found, typically *Nephthya mollis* (upper area), various *Xenias*, and the curious nephthyid *Paralemnalia thyrsoides* mimicking an Acropore such as *A. quelchi*. The hydroid *Aglaophenia cupressina* and the sponge *Phyllospongia ridleyi* (upper area) are frequent.

This Moat contrasts in almost all its features with the Low Isles Moats, and has more in common with the inshore part (first 200 feet) of the Seaward Slope on the windward side of Low Isles (see Traverse III, level section) than with any other part of Low Isles reef. Here also occur the giant *P. eydouxi* (absent elsewhere on Low Isles and on the leeward side of Yonge Reef), *Leptastrea ehrenbergana* (present elsewhere on Low Isles on coral heads), the very large massive corals, and acropores such as *A. decipiens*, *A. abrotanoides*, and the stout variety of *A. gemmifera* (occurring nowhere else on Low Isles).

INNER PARTS OF THE REEF.

The leeward side of the reef from the Reef Crest passes through the Inner Moat to the Boulder Zone, and so to the Anchorage Coral Zone and Zone of Coral Heads (see Vol. III, No. 2, pp. 34 and 85, and Spender, 1930, p. 33). In the Anchorage Coral Zone the substratum changes from rock to rock intersected by sandy pools, the sandy floor sloping gradually from 1-2 feet to 2-3 fathoms below low water. The rock surface is much rougher and is less heavily covered by nullipores, and lies in boulders and uneven masses. The upper area on Plate XVI illustrates a typical portion of the Anchorage Coral Zone; the water here lies about 4 feet deep in the pools (see also Vol. III, No. 2, Plate XXIV, fig. b). The Anchorage Coral Zone passes gradually into that of Coral Heads, masses of coral rock rising precipitously from the sandy floor. These coral heads are several or many yards across, and their tops are covered with a rich growth of corals which may overhang at the edges. The edge of a coral head is mapped below on Plate XVI (see also Vol. III, No. 2, Plate XXIV, fig. 2). These zones show a preponderance of branching corals, particularly Acropores, and show a certain resemblance to the areas so named on Low Isles.

On the Anchorage Coral Zone on Yonge Reef (Plate XVI, upper area), *A. palifera* and both coarse and fine varieties of *A. gemmifera* are conspicuous on the higher parts, while large "stag-horn" acropores grow into the pools. Other noteworthy branching forms are *Seriatopora*, *Pocillopora verrucosa*, *P. danae* and *Stylophora*. It will be noticed that *A. gemmifera*, *A. palifera* and *P. verrucosa* also occur in the Outer Moat, but that unlike the Outer Moat, *P. eydouxi* is here absent. In the presence of Fungias, *Seriatopora*, *Stylophora*, *P. danae* and stag-horn acropores a resemblance is seen to the Low Isles Anchorage. The massive corals are various. They may be very large and grow so high as to show dead flat tops. *Goniastrea retiformis*, *Favia abdita*, *F. halicora* and *Goniastrea K. 5** are very frequent; these are corals found in most situations on Low Isles and on Yonge Reef. Fungias and *F. favius* are more particular in habitat, and occur here and on coral heads and leeward slopes and moats of Low Isles, but are not frequent on other parts of Yonge Reef. *F. vasta*, found in the deeper parts of the Low Isles leeward slope, is also found on the Yonge Reef anchorage zone.

Coral Heads have already been described, Vol. II, No. 2, p. 85, and the map below on Plate XVI showing the edge viewed from above may be compared with the Low Isles coral heads viewed from the side (Plate XII, and Vol. III, No. 2, Plate XVII, fig. 1).

In conclusion, it may be said that the examination of the above areas, although not extensive, illustrates certain general features in comparison with Low Isles.

On the two reefs many similar corals occur, and the external appearance of most massive corals of the same species seems identical on the two reefs. With the branching corals, particularly the Acropores, such is not the case, and much greater variety of form is apparent among corals growing on different regions. A few are constant in external appearance in different localities, such as *A. decipiens*, coarse and fine forms of *A. gemmifera*, etc., but the appearance of others varies somewhat from one region to another, or they are replaced by slightly different varieties or growth forms in endless combinations.

* This species could not be satisfactorily determined, and is so labelled in the collection deposited in the British Museum.

Until the relations of the varying growth forms and species of Acropores is elucidated, adequate description of coral associations becomes impossible.

On the two reefs certain corals seem to be very accommodating in their requirements, and are found in a great variety of habitats. Such are *Goniastrea retiformis*, *Favia abdita* and *F. halicora*, which occur alike in moats, leeward and windward slopes and edges of both reefs. Other corals are less accommodating, and occur mainly in certain habitats, such as leeward slopes and moats, ex. *F. vasta* and *Fungia*, or the windward slopes and outer regions, ex. *Pocillopora eydouxi* and *Acropora decipiens*, etc.

On the one reef a definite zonation in the distribution of the coral fauna may be clearly defined (as shown by distribution graphs for Low Isles). On Yonge Reef, where environmental conditions differ, the zonation of corals shows some similarities to that on Low Isles, but some differences. The region seaward from the reef crest on Yonge Reef resembles the windward slope of Low Isles in some of its physical features and in characteristic corals such as *P. eydouxi*, etc., and the leeward side of Yonge Reef also shows many features in common with the leeward slopes and anchorage of Low Isles. However, on Yonge Reef, but not on Low Isles, several corals characteristic of the seaward sides are found on the leeward side as well, such as the coarse variety of *A. gemmifera*; and corals such as *Stylophora*, *Seriatopora* and *F. vasta*, which occur on the leeward side of both reefs, are found in deeper water on the windward slope of Low Isles. This may indicate that the conditions for coral growth on the seaward slope of the windward side of Low Isles may be in some degree intermediate between those present on the leeward and seaward sides of Yonge Reef.

SUMMARY.

1. An account is given of a quantitative survey of the corals and algae present along a strip of reef one yard wide, made over two traverses across the lee side of Low Isles. The survey was continued down the seaward slopes of the reef by the use of a diving helmet. A less detailed account of a third traverse across the windward side of the reef is given.

2. Measurements of levels and distances and level sections along the traverses are given.

3. The main physical features along the traverses which may influence coral and algal growth are recorded.

4. Large-scale maps of limited areas illustrate the comparisons of different regions of the reef in detail, and serve as a record of the present state of certain parts of Low Isles reef.

5. The survey records details of the varieties and numbers of algae and corals on each square yard, passing through the stringent physical conditions prevailing in the Western Moat, and over the more luxuriant coral zones on the Seaward Slopes of the reef. The Traverses end (1) on the muddy sea floor, devoid of corals and algae, at about 20 feet below datum, and (2) on a barren sandy stretch of the floor of the Anchorage at 5.5 feet below datum. On Traverse III records are given of corals down to a depth of 16, but coral growth continues far below this level.

6. Algae are most abundant in the shallower parts of the Moat, and corals in the deeper part of the Moat and on the Seaward Slopes.

7. A zoning of the corals on the Seaward Slopes is shown. It is correlated in the first place with the levels of the substratum. On Traverse I the maximum growth of corals, in both numbers of species and of colonies, lies at about 2 feet below datum; on Traverse III luxuriant coral growth extends into much deeper water.

8. The environmental factors which are likely to influence coral and algal growth along the traverses are considered. The most important of these are probably (1) level of the substratum in relation to that of low water and to the maximum duration of low tides, (2) the ranges of temperature and salinity of the water, and (3) the nature and amount of the sediments which are deposited and which may lie undisturbed on rocks and corals.

9. Observations and records on Traverse I indicate that at slight depths the deposition of fine grey mud, which is not entirely removed from projecting surfaces by water movements, is unfavourable for corals, and here constitutes a limiting factor for coral growth.

10. This survey is briefly compared with existing detailed accounts of restricted areas on other reefs.

11. Large-scale maps are given of limited areas from typical zones of an Outer Barrier reef (Yonge Reef) for comparison with Low Isles.

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TABLES OF LEVELS ALONG THE TRAVERSES.

Levels along Traverse I. Distances are measured in feet from the beginning of the traverse on the Thalamita flat; see Text-fig. 1, and level section.

Distances.	Heights above or below datum in feet.		
0	.	2.79	
12	.	2.70	
25	.	2.71	
35	.	2.59	
50	.	2.51	
64	.	2.49	
74	.	2.55	
85	.	2.59	
100	.	2.54	
110	.	2.48	
120	.	2.43	
142	.	2.47	
155	.	2.39	
170	.	2.58	
185	.	2.45	
200	.	2.44	
215	.	2.45	
230	.	2.50	
247	.	2.40	
260	.	2.41	
273	.	2.54	
285	.	2.39	
289	.	2.92	(" platform " of <i>M. ramosa</i>).
300	.	2.39	
315	.	2.50	
325	.	2.89	" "
335	.	2.31	
345	.	2.39	
352	.	2.95	" "
360	.	2.29	
375	.	2.41	
389	.	2.13	
397	.	2.94	" "
400	.	2.19	
410	.	2.22	
416	.	3.01	" "
417	.	2.86	(" massive <i>Porites</i>).
427	.	2.15	
435	.	3.00	(" <i>M. ramosa</i>).
441	.	2.34	
450	.	2.08	
455	.	3.00	" "
462	.	2.28	
467	.	3.00	" "
480	.	2.17	
493	.	2.14	
500	.	2.19	
516	.	1.87	
527	.	2.24	

Distances.	Heights above or below datum in feet.		
537	.	2.84	(" platform " of massive <i>Porites</i>).
538	.	2.73	(" " <i>M. ramosa</i>).
541	.	1.78	
552	.	2.91	" "
560	.	1.90	
570	.	2.28	
577	.	2.99	" "
583	.	2.01	
593	.	2.85	(" massive <i>Porites</i>).
596	.	2.01	
599	.	2.93	(" <i>M. ramosa</i>).
615	.	2.83	(" massive <i>Porites</i>).
617	.	2.56	
630	.	1.96	
643	.	2.05	
650	.	2.87	
664	.	2.35	
674	.	2.41	
689	.	2.37	
698	.	2.60	
699	.	2.76	
710	.	2.86	
730	.	2.97	
755	.	2.98	
771	.	1.98	
780	.	2.13	
790	.	1.55	
800	.	0.88	
815	.	0.65	
832	.	-0.03	
845	.	-0.14	
852	.	-0.70	
854	.	0.35	(" <i>Acropora polymorpha</i>).
865	.	-1.24	
868	.	0.26	(" <i>Acroporas</i>).
880	.	0.11	(top of corals).
882	.	-1.12	
892	.	-1.97	
900	.	-2.05	
910	.	-2.85	
922	.	-0.05	(top of rock).
926	.	-3.50	
929	.	-2.10	"
943	.	-4.60	
960	.	-0.40	"
967	.	-6.60	
981	.	-5.50	
1000	.	-8.60	(base of rock 6 feet high).
1007	.	-8.50	(" 7 ").
1027	.	-15.00	
1045	.	-17.00	
1059	.	-17.50	
1085	.	-18.50	
1089	.	-18.50	

Levels along Traverse II. Distances are measured in feet from the beginning of the Traverse on the beach; see Text-fig. 1 and level sections.

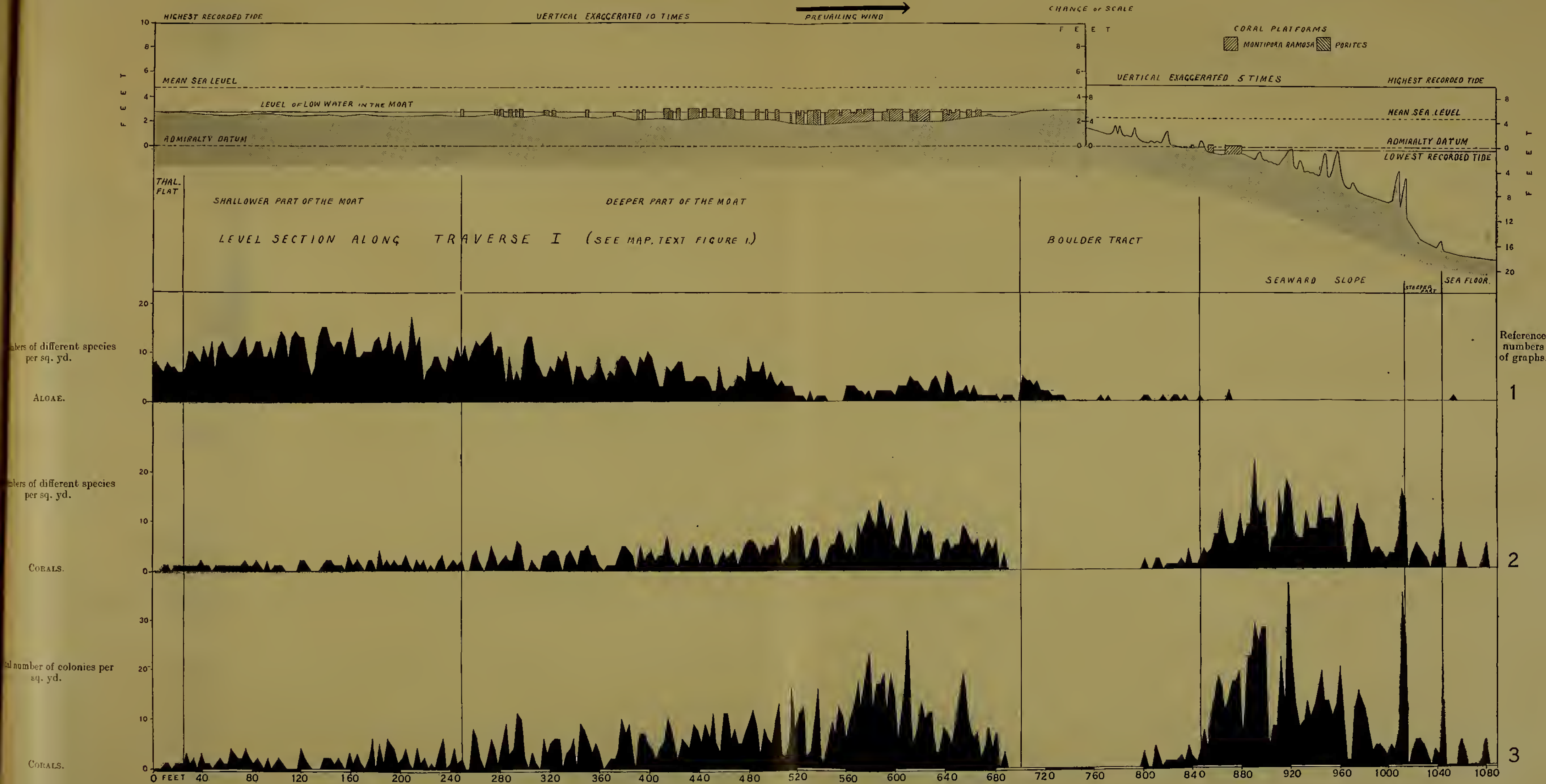
Distances.	Heights above or below datum in feet.		
0	.	12.08	
35	.	8.26	
55	.	5.58	
77	.	4.18	
78	.	4.92	
100	.	3.44	
105	.	2.52	
120	.	1.43	
133	.	0.73	
134	.	1.43	
150	.	2.89	
159	.	3.06 (top of rocks).	
165	.	1.20	
174	.	0.38	
178	.	1.50 ("platform" of <i>M. ramosa</i>).	
201	.	1.49	" "
216	.	1.46	" "
217	.	1.16	
230	.	1.60	" "
245	.	1.50 (" " and rocks).	
251	.	1.16	
270	.	0.86	
282	.	0.90	
291	.	0.85	
295	.	2.06 (top of <i>A. hebes</i>).	
299	.	0.54	
310	.	-0.19	
324	.	-0.65	
325	.	0.48 (" coral platform).	
336	.	-0.81	
342	.	0.59	" " "
352	.	0.61	" " "
359	.	-1.38	
367	.	0.17 (" rocks and coral).	
380	.	0.17	" " "
395	.	0.52	" " "
406	.	0.24	" " "
409	.	-2.21	
417	.	-0.12	" " "
422	.	-1.40	
425	.	-0.41 (" coral).	
430	.	-2.49	
432	.	0.00 (rock and coral).	
450	.	0.25	" "
460	.	-0.99 (top of coral).	
470	.	-2.07	" "
476	.	-3.80	
482	.	-5.20	
488	.	-5.20	

Levels along Traverse III. Distances are measured in feet from the beginning of the traverse on the Inner Rampart; see Text-fig. 1, and level section.

Distances.	Heights above or below datum in feet.
0	5.49
62	4.56
75	7.45
268	3.27
300	2.53
350	2.03
415	0.97
460	0.14
480	-0.20
503	-0.70
520	-1.30
535	-1.40
560	-1.90
571	0.80 (top of rock).
577	-2.00
588	-3.50
606	0.20 " "
619	-4.20 " "
628	-0.40 " "
643	-4.40
652	-5.20
679	-8.00
703	-8.00
721	-9.00
735	-10.00
744	-10.00
763	-10.00
783	-12.00
807	-16.00
835	-16.00
867	-16.00
877	-20.00
906	-21.00
923	-29.00
941	-44.00
945	-48.00
964	-51.00
991	-57.00
1051	-65.00
1075	-74.00
1155	-86.00



Brit. Mus. (Nat. Hist.).



TRAVERSE I.—Distribution of Algae and Corals. Total numbers of colonies and species.

Brit. Mus. (Nat. Hist.).

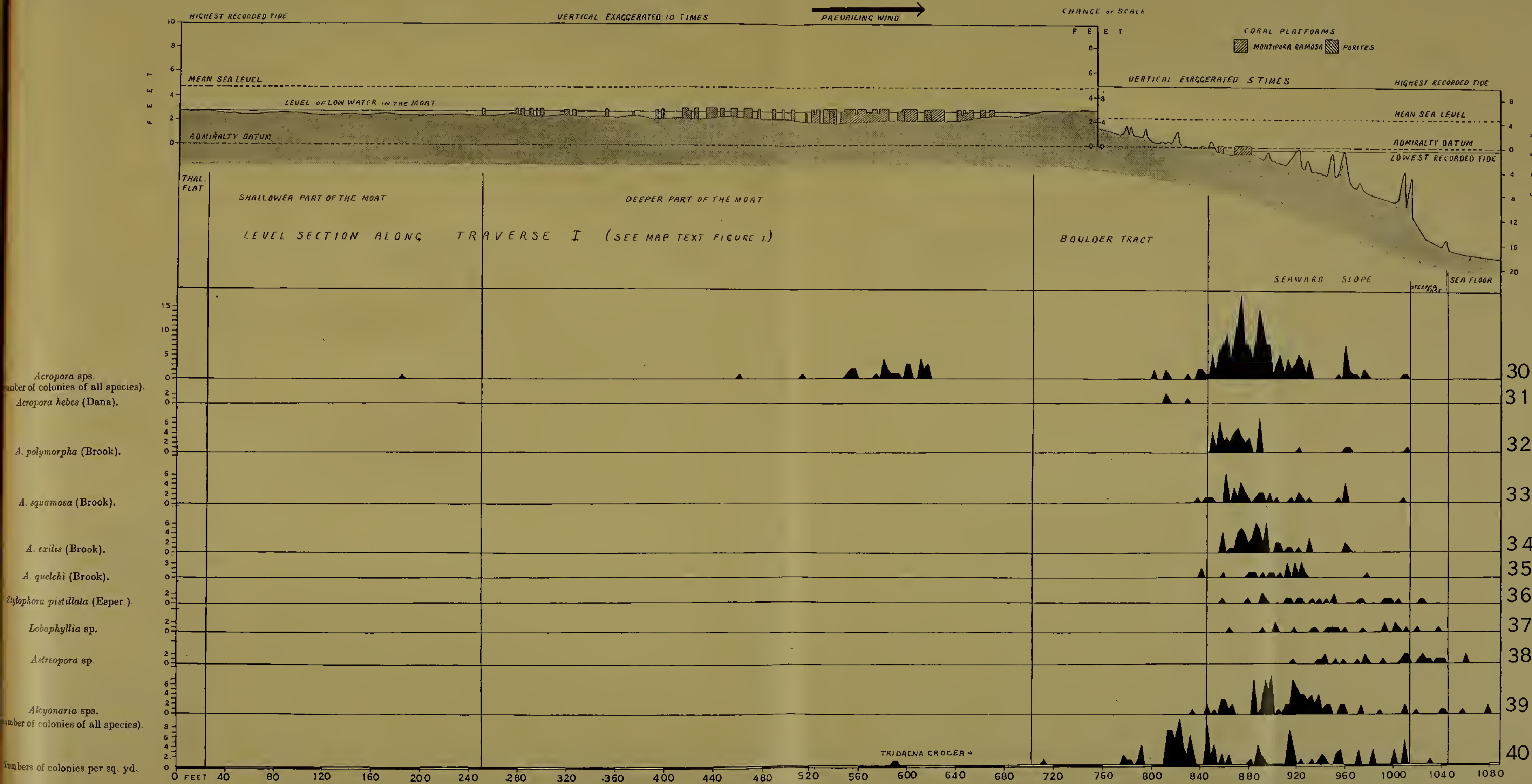


TRAVERSE I (continued).—Distribution of Plants.

Where possible the numbers of separate plants per square yard are given; where this is not possible, the distribution is recorded in terms of presence or absence per square yard (ex. *Roschera glomerulata*, Graph 11), in some cases relative abundance is also indicated, a wide black area signifying the occurrence of the plant in greater abundance than a narrow black area (ex. *Laurencia papillosa*, Graph 12).



Brit. Mus. (Nat. Hist.).

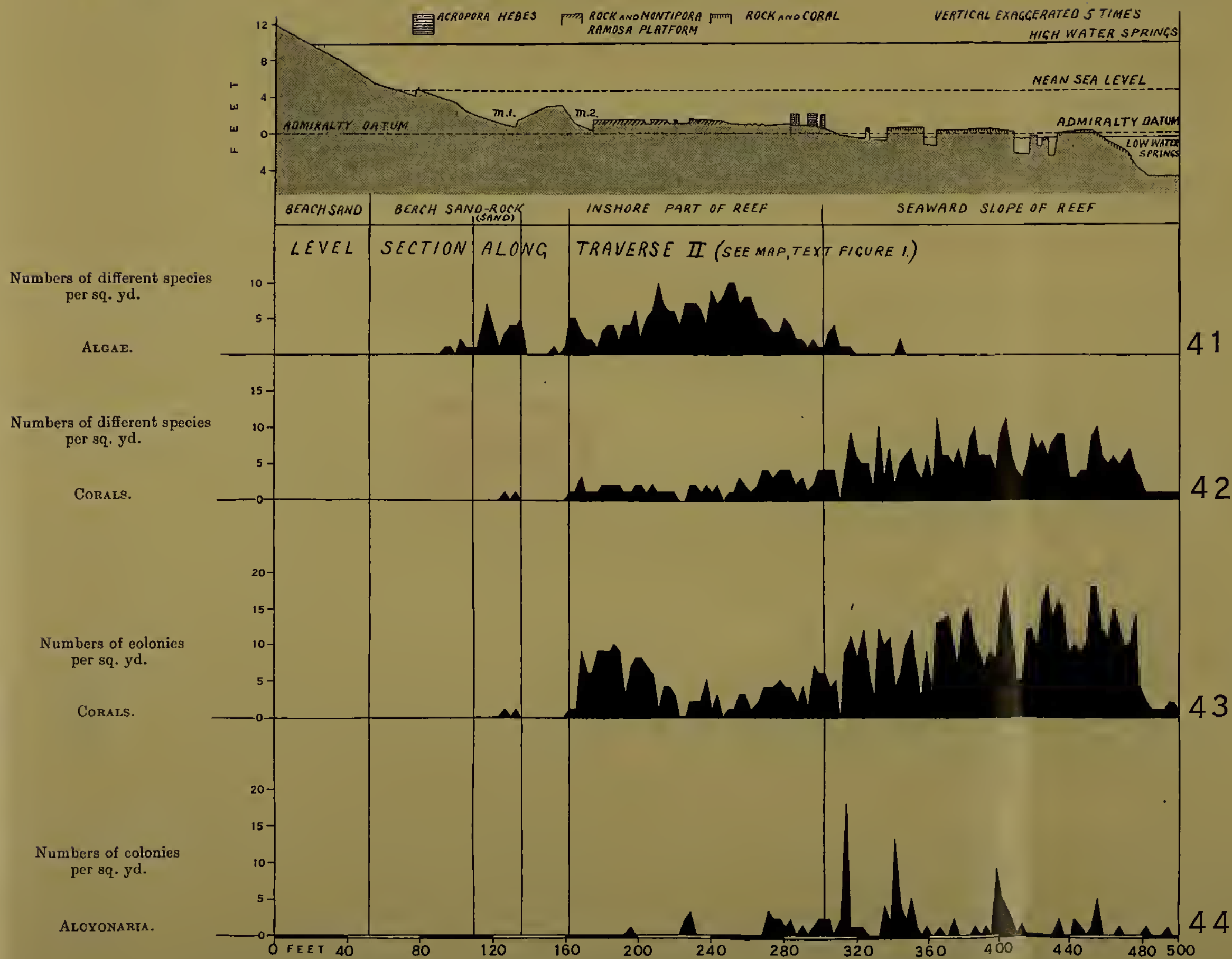


GREAT BARRIER REEF EXPEDITION 1928-29.

Brit. Mus. (Nat. Hist.).

REPORTS, VOL. III, No. 10.

PLATE V.



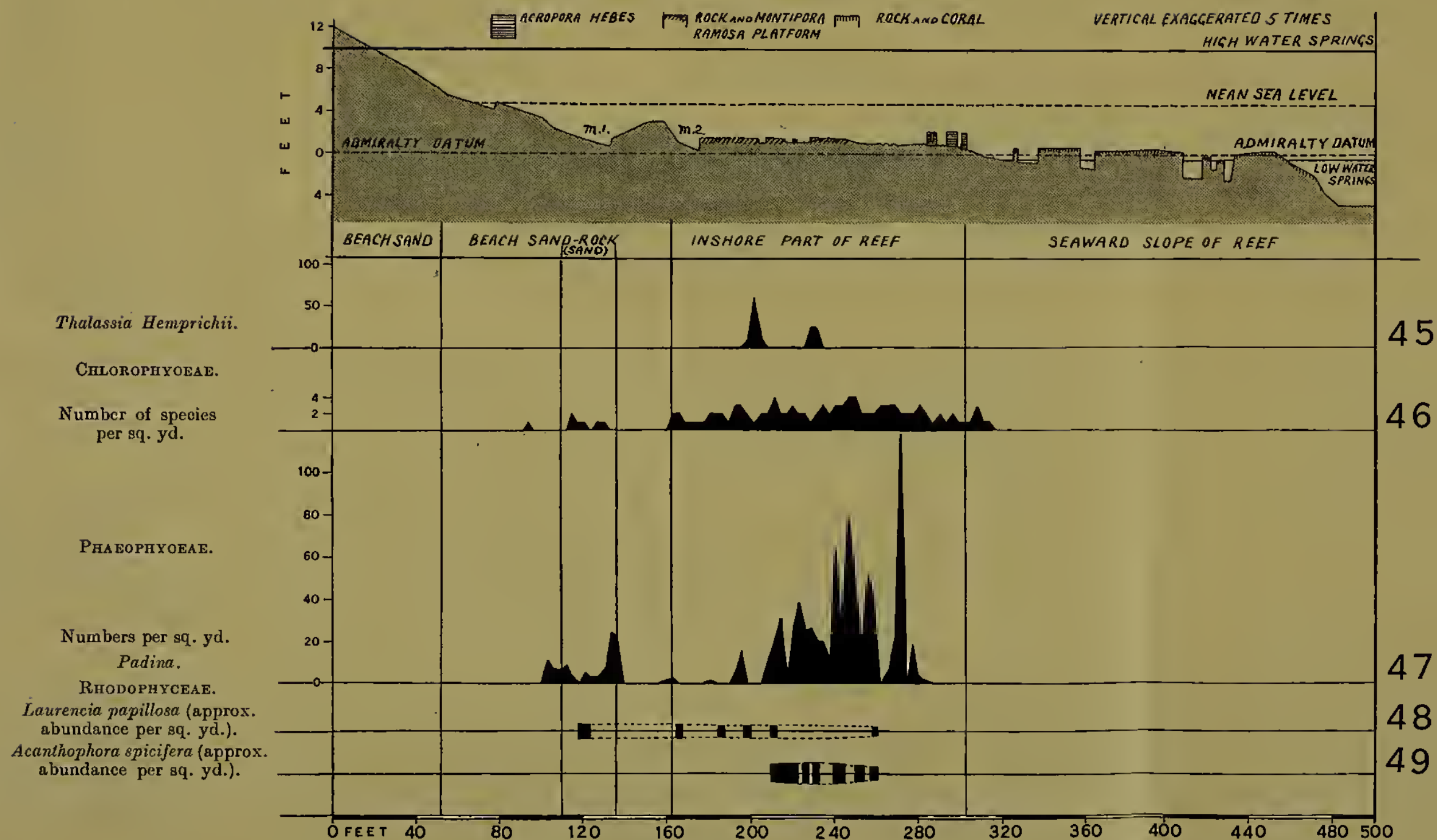
TRAVERSE II.—Distribution of Algae, Corals and Alcyonaria. Total numbers of colonies and species.

GREAT BARRIER REEF EXPEDITION 1928-29.

Brit. Mus. (Nat. Hist.).

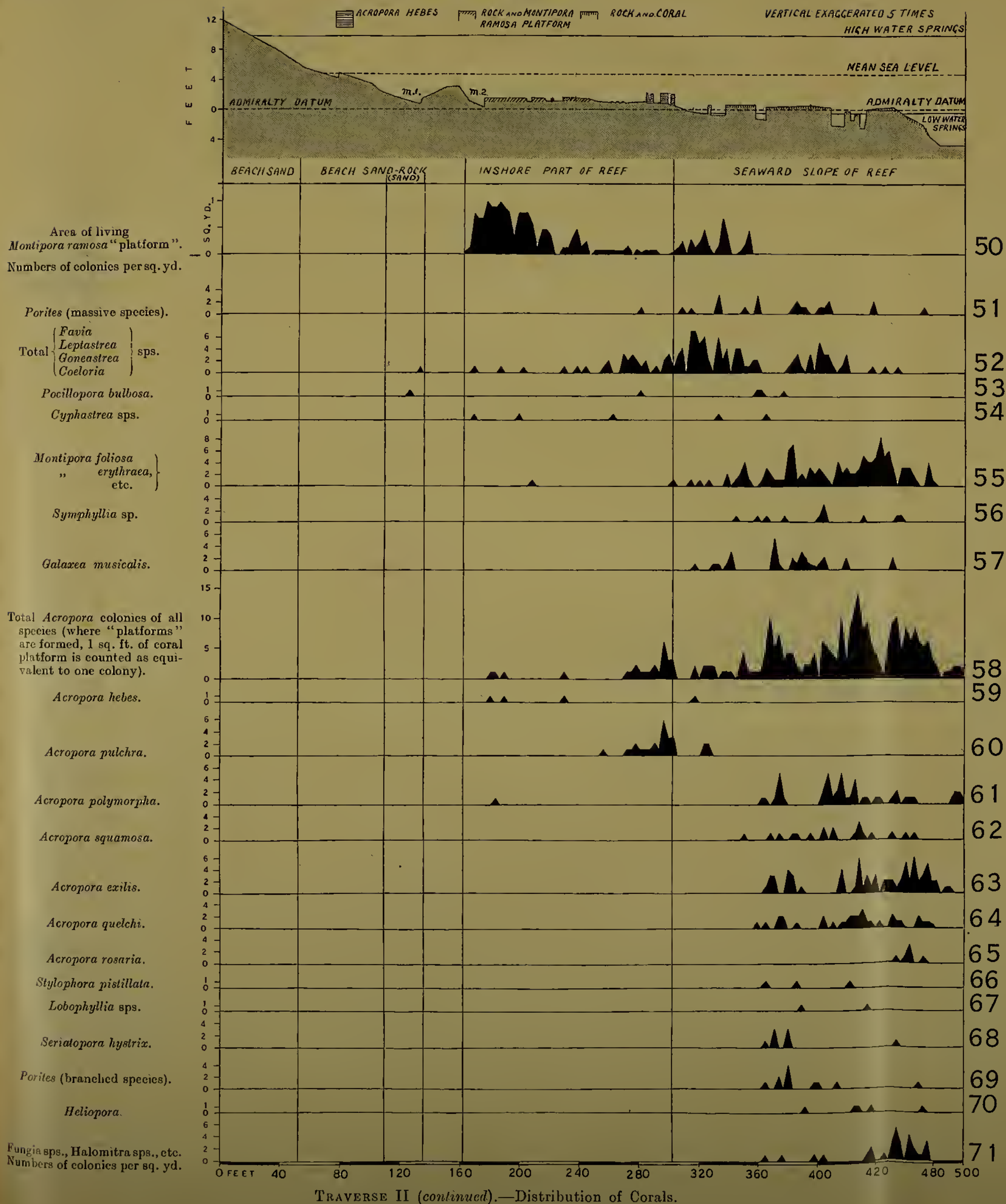
REPORTS, VOL. III, No. 10.

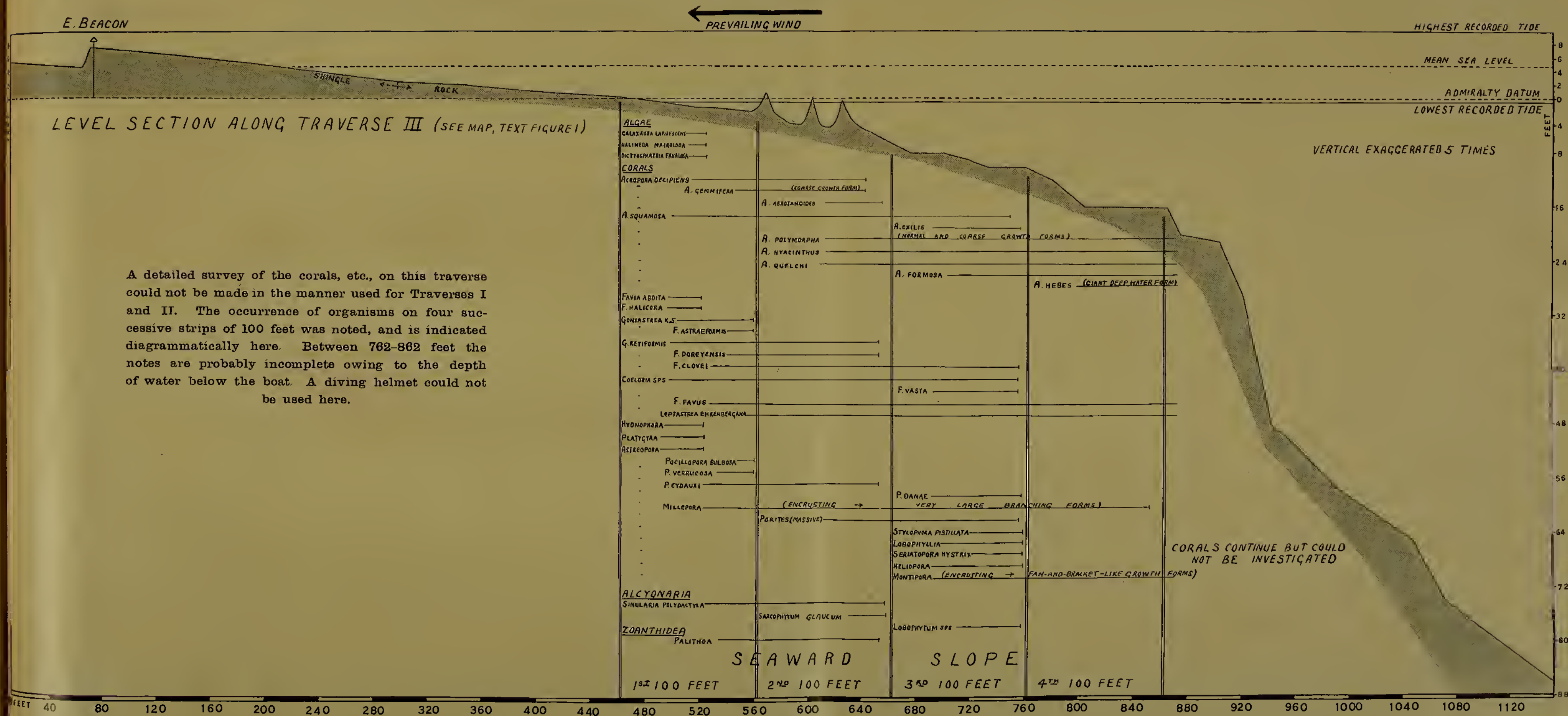
PLATE VI.



TRAVERSE II (continued).—Distribution of Plants.

NOTE.—Where possible the numbers of separate plants per square yard are given; where this is not possible, the distribution is recorded in terms of presence or absence per square yard, a wide black area signifying greater abundance than a narrow black area.





A detailed survey of the corals, etc., on this traverse could not be made in the manner used for Traverses I and II. The occurrence of organisms on four successive strips of 100 feet was noted, and is indicated diagrammatically here. Between 762-862 feet the notes are probably incomplete owing to the depth of water below the boat. A diving helmet could not be used here.

TRAVERSE III.

DESCRIPTION OF PLATE IX.

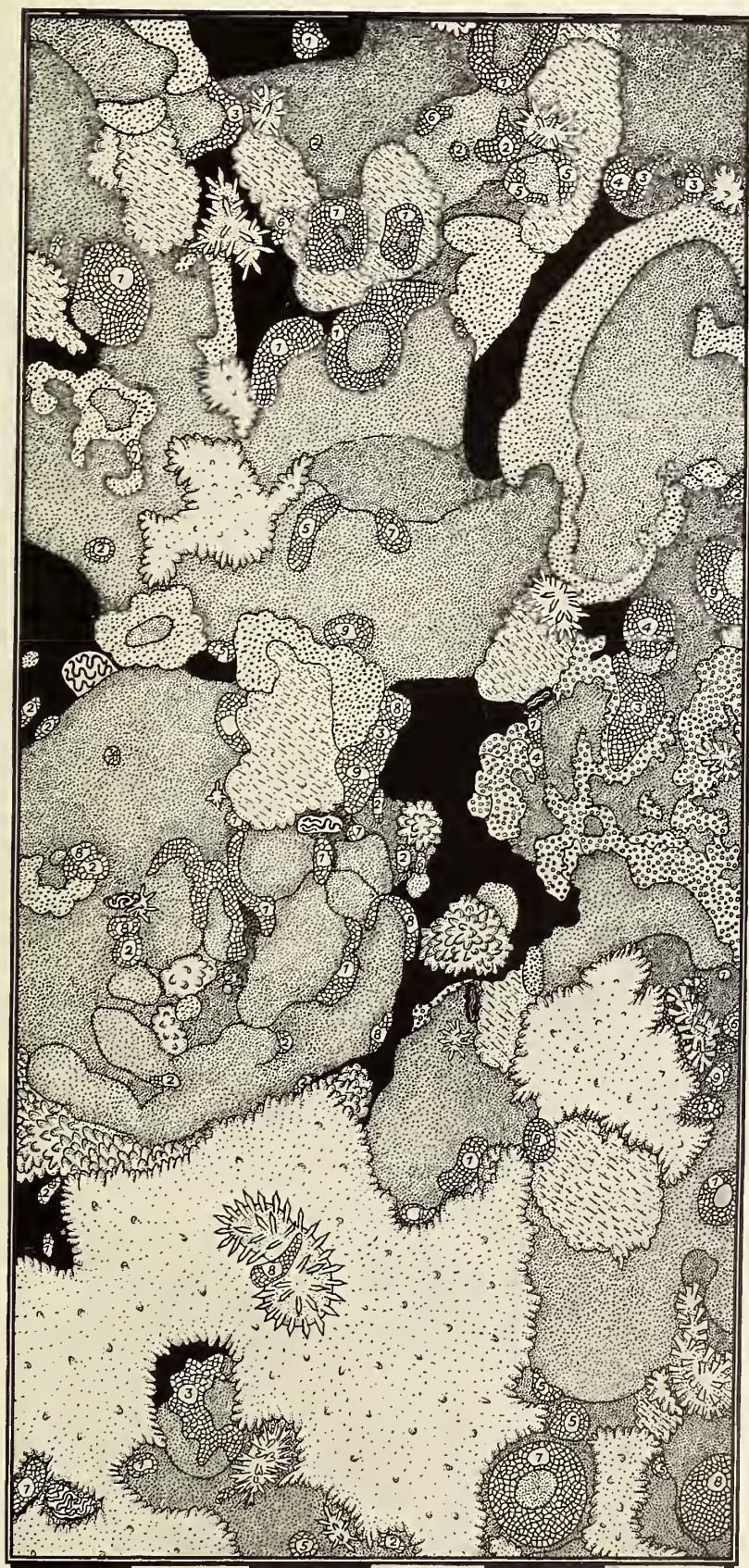
Large-scale map of an area in the deeper part of the WESTERN MOAT where coral growth for the moat is at a maximum. Scale 1/18. The area is crossed by Traverse I between 558 and 569 feet. (See Level Section and Text-fig. 1.)

Water to a depth of about 0.7 feet is held up at low water over the sand (black). The dead coral rock (grey and stippled) is darker and lighter in tone at lower and higher levels respectively; the higher parts of such rock lie at the surface level of low-water, all other parts being well submerged. A key to the corals is given at the side. Algae were few, and too small to represent graphically.

Coral growth is here active, and at times has covered much of the bottom. Now much dead coral rock provides sites for the attachment and growth of fresh colonies. The upward growth of all corals is checked about low-water level, giving platforms with flat tops of the branching *M. ramosa* and of the massive growth forms of *Porites* and *Favia*. The tops of the massive corals are frequently dead, either entirely, or over a small central area on the smaller colonies. The large rounded block of coral rock about 4 feet in diameter on the left-hand side represents the dead remains of a flat-topped platform of a massive coral. It now serves as an attachment for fresh coral growth, both at the sides and also on the top, where it has been worn away to a sufficient depth below low-water level.

Key to species of *Favia*, etc., indicated by numbers on the map:

- | | |
|-----------------------------------|----------------------------------|
| 1. <i>Goniastrea retiformis</i> . | 6. <i>Goniastrea pectinata</i> . |
| 2. <i>Leptastrea roissiana</i> . | 7. <i>Favia astraeiformis</i> . |
| 3. <i>Favia abdita</i> . | 8. „ <i>halicora</i> . |
| 4. „ <i>doreyensis</i> . | 9. <i>Coeloria daedalea</i> . |
| 5. „ <i>favus</i> . | |



KEY.

-  *Montipora ramosa*.
-  Flat-topped "platform" of *Montipora ramosa*.
-  Dead *Montipora ramosa* "platform".
-  Massive *Porites*.
-  *Favia*, etc. (central number indicates species; see legend).
-  *Psammocora gonagra*.
-  *Pocillopora bulbosa*.
-  *Acropora* sps.
-  *Montipora foliosa*, etc.
-  *Symphyllia*.
-  *Coeloria*.
-  *Platygyra*.
-  *Tridacna crocea*.
-  Coral rock.
-  Water covering sand.

1 2 3 4 5 feet.

DESCRIPTION OF PLATE X.

Large-scale map of an area in the MADREPORE MOAT. Scale 1/18. The position of this area is seen in Text-fig. 1. It lies inside the ring marked in the Madreporo Moat.

This area may be compared with that shown in Plate I of the Western Moat. Here in the Madreporo Moat the depth of water (0·6 feet) held up at low water over the sand (black) is slightly less than that in the Western Moat (0·7 feet over the region seen in Plate I), and the physical conditions in the two regions are very similar. Corals here are less varied and abundant, and the plants are more numerous. Almost all the corals are living. Extensive platforms of *M. ramosa* and *Acropora hebes* are present, and massive growths of *Porites*, which have not yet reached low-water level, and are thus entirely living and not flat-topped. Unlike the Western Moat, there is very little dead coral material or coral rock (stippled grey) upon which other corals and algae may be attached. Algae are conspicuous and are attached to the few rocks present, and the expansive sandy areas (black) support an abundance of *Thalassia Hemprichii*. The larger animals lying on the sand and elsewhere are also shown: the blue starfish, *Linkia laevigata*, two clams, *Tridacna derasa* (left-hand side) and *T. crocea* boring in the coral rock, and *Synapta maculata*.

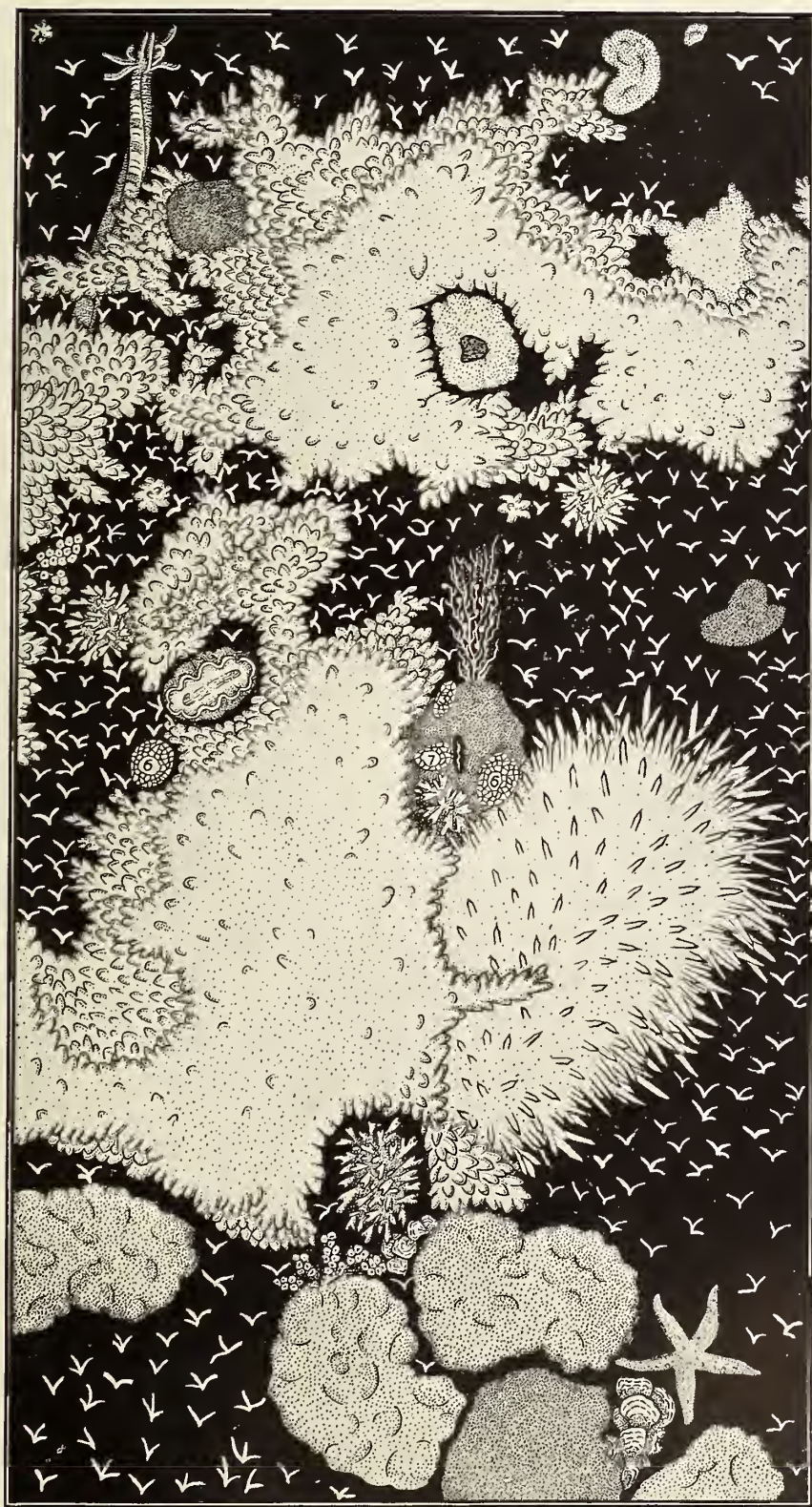
It is possible that this area now shows a young stage of a moat fauna and flora, and that the Western Moat mapped in Plate I shows an older stage of the same formation. Further growth of the corals now seen in Plate II would lead to the formation of flat-topped platforms of massive corals of increasing size, and the sandy bottom would become more and more covered by coral growth, resulting in the exclusion of many of the plants. Death of the larger massive forms would lead to the state seen in Plate I.

Key to species of *Favia*, etc., indicated by numbers on the map:

3. *Favia abdita*.

6. *Goniastrea pectinata*.

7. *Favia astraeiformis*.



1 2 3 4 5 6 feet.

KEY.

-  *Montipora ramosa*.
-  Flat-topped "platform" of *M. ramosa*.
-  Massive *Porites*.
-  *Favia*, etc. (central number indicates species; see legend).
-  *Pocillopora bulbosa*.
-  *Acropora hebes*.
-  *Tridacna crocea* burrowing in rock.
-  Coral rock.
-  *Thalassia Hemprichii* growing in sand.
-  *Padina*.
-  *Turbinaria*.
-  *Sargassum lanceolatum*.

DESCRIPTION OF PLATE XI.

(a) Large-scale map of an area on the SEAWARD SLOPE crossed by Traverse I between 892 and 961 feet (see level section). Scale 1/18.

Coral growth on Traverse I is here at a maximum, and the region is dominated by species of *Acropora*. The level of water changes directly with the state of the tide. The sandy bottom (black) lies at about 2 feet below datum level. The coral rock (stippled grey) is darker in tone at lower levels. The top of the boulder shown in the upper part of the plate rises almost to datum level. Its upper surface bears massive colonies of *Favia*, etc., and the burrowing clam *Tridacna crocea*; while on the steeper sides brackets of Acropores and other branching corals project one above another. Only parts of such brackets can be seen in a view from above. The top of the rock on the lower part of the plate is at a deeper level, only just above that of the sand, and bears a great variety of corals and some alcyonaria on its surface.

(b) Large-scale map of an area on the SEAWARD SLOPE crossed by Traverse II between 366 and 373 feet, and situated just beyond pool 2 (see level section). Scale 1/18.

Coral growth here is particularly abundant. Dead coral rock (stippled grey) rises to just above datum level from a sandy pool (black) with a bottom level of 1.4 feet below datum. The rock is almost completely covered by a large variety of corals, eleven species being present over 2 square yards.

Key to species indicated by numbers on the map :

<i>Favia</i> , etc.	<i>Acropora</i> .
1. <i>Goniastrea retiformis</i> .	1. <i>Acropora squamosa</i> .
5. <i>Favia fava</i> .	2. " <i>exilis</i> .
7. " <i>astraeiformis</i> .	3. " <i>polymorpha</i> .
8. " <i>halicora</i> .	4. " <i>hebes</i> .
10. <i>Goniastrea</i> K. 5.*	5. " <i>quelchi</i> .
	6. " <i>gemmifera</i> .
	7. " <i>hyacinthus</i> .
	8. " <i>variabilis</i> .

* This species could not be satisfactorily determined, and is so labelled in the collection deposited in the British Museum.

KEY.



Porites branched in (b); massive in (a and b).



Favia, etc. (central number indicates species; see legend).



Pocillopora danae.



Acropora (central number indicates species; see legend).



Montipora foliosa,
,, *erythraea*, etc.



Symphyllia.



Lobophyllia.



Platyggyra.



Galaxea fascicularis.



Stylophora pistillata.



Orbicella.



Astreopora.



Goniopora.



Merulina.



Pavona.



Echinopora.



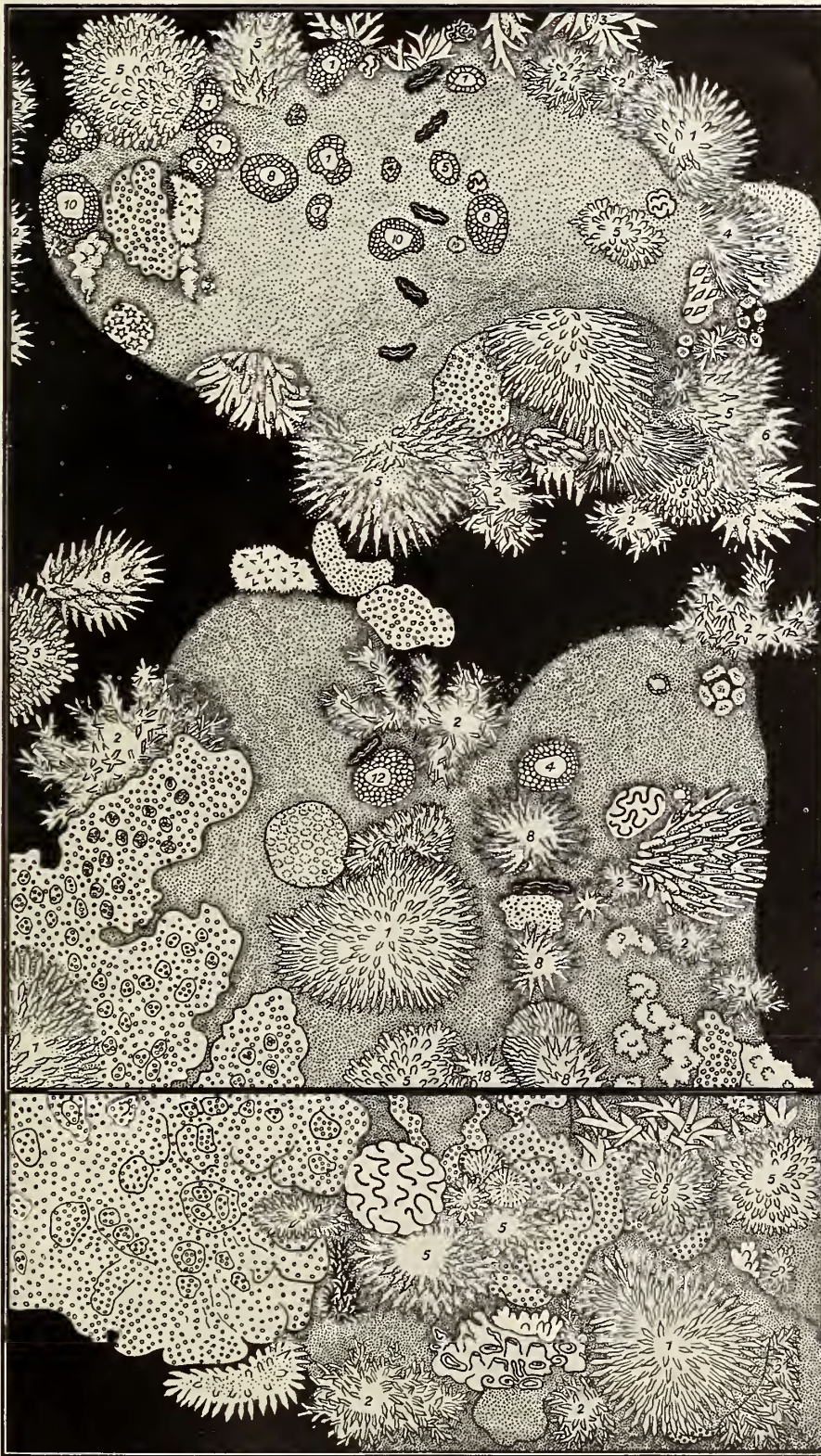
Millepora.



Alcyonium pachyclados.



Seriatopora and *Tridacna crocea*
in rock. Sand (black).



1 2 3 4 5 6 feet.

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DESCRIPTION OF PLATE XII.

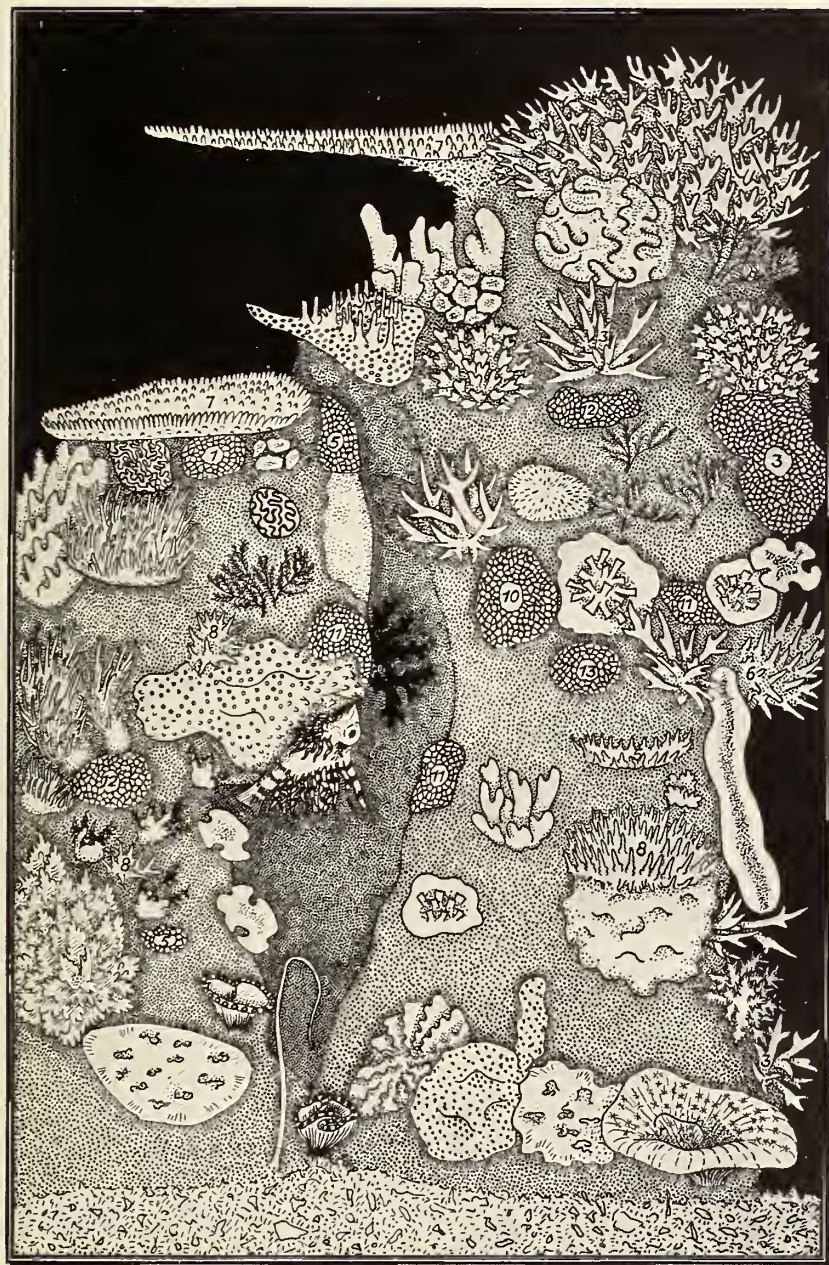
Large-scale map of part of the vertical face of a CORAL HEAD situated off the north-east corner of Low Isles in line with beacons C and B (Text-fig. 2), and marked at "X" in Text-fig. 2b. Scale 1/18.

The top of the coral head rises almost to datum level, and the sea floor, composed of sand and shingle, lies at 9-10 feet below datum. Water is represented by black and the rock by stippled grey areas. No mud lies on the rocks or on the shingle of the sea floor. The side of the coral head is well covered by corals comprising a large variety of genera and species (compare the rich coral zone seen in Plate III, where the rock is more overgrown by corals, but not so many different forms are present). Coral growth persists to the base of the coral head, where encrusting or flattened colonies of *Echinopora* and *Porites* and funnel-shaped *Turbinaria* and *Podobacia* are present. *Millepora* of various growth forms is more frequent here than in the other types of coral area which are shown in Plates IX-XI, and becomes more finely branched towards the top of the coral head. At the top of the rock horizontal projecting brackets of *Acropora hyacinthus* and *Montipora erythraea* occur much as on the coral heads situated just inside the outer barrier reefs. A black *Dendrophyllia* is seen growing in a poorly-illuminated situation on the rock, as is usual on Low Isles. Alcyonaria on this rock are also frequent and varied; *Spongodes* and *Juncea* growing near the base are not found in the shallower regions about Low Isles. The Hydroid, *Aglaophenia*, is large and frequent. In shallower situations hydroids are usually very small and fewer.

Key to species indicated by numbers on the map :

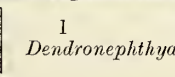
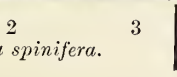
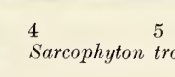
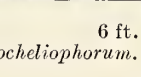
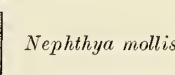
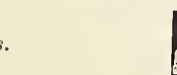
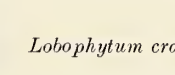
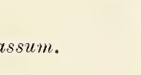
- | <i>Favia</i> , etc. | <i>Acropora</i> . |
|---------------------------------------|---------------------------------|
| 1. <i>Goniastrea retiformis</i> . | 3. <i>Acropora polymorpha</i> . |
| 3. <i>Favia abdita</i> . | 6. ,, <i>gemmaefera</i> . |
| 5. ,, <i>favus</i> . | 7. ,, <i>hyacinthus</i> . |
| 10. <i>Goniastrea</i> K. 5.* | 8. ,, <i>variabilis</i> . |
| 11. <i>Leptastrea ehrenbergiana</i> . | |
| 12. <i>Favia clouei</i> . | |
| 13. ,, <i>laxa</i> . | |

* This species could not be satisfactorily determined, and is so labelled in the collection deposited in the British Museum.



KEY.

-  Massive *Porites*.
-  *Favia*, etc. (central number indicates species; see legend).
-  *Psammocora gonagra*.
-  *Pocillopora danae*.
-  *Acropora* (central number indicates species; see legend).
-  *Montipora* sps.
-  *Symphyllia*.
-  *Lobophyllia*.
-  *Platygyra*.
-  *Echinopora*.
-  *Turbinaria*.
-  *Dendrophyllia*.
-  *Podobacea*.
-  *Astreopora*.

- | | | | | | |
|---|---|---|--|--|---|
|  1 |  2 |  3 |  4 |  5 |  6 ft. |
|  7 |  8 |  9 |  10 |  11 |  12 |

DESCRIPTION OF PLATE XIII.

Large-scale map of two areas close together situated near Traverse II on the landward part of the SEAWARD SLOPE (see level section and Text-fig. 2), where alcyonaria are particularly abundant. Scale 1/18.

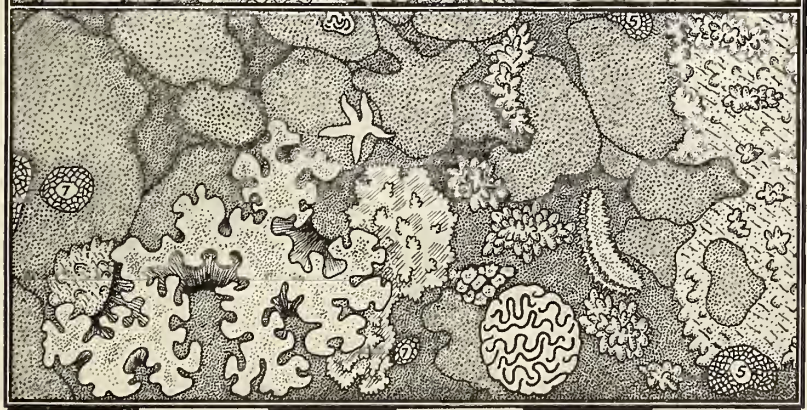
The level of the sand (black) is about 1 foot below datum. Coral rock very much worn (stippled grey) lies well below datum level, and the living and semi-dead colonies of *M. ramosa* rise a little above datum level. The Fungidae, which become abundant on the Seaward Slope, are here present, and the alcyonaria are abundant and varied.

Sinularia flexibilis is seen in various stages of expansion. The underlying rock is only exposed when the colonies are contracted, as in the upper left-hand corner of (a). A large specimen of *Sarcophyton trocheliophorum* in the contracted state is seen in (b). The larger animals present are also shown: the boring clam *Tridacna crocea*, the blue starfish *Linkia* and the holothurian *Stichopus*.

Key to species indicated by numbers on the map:

- | | |
|-----------------------------------|-------------------------------|
| 1. <i>Goniastrea retiformis</i> . | 8. <i>Favia halicora</i> . |
| 4. <i>Favia doreyensis</i> . | 9. <i>Coeloria daedalea</i> . |
| 5. „ <i>favus</i> . | 10. <i>Goniastrea</i> K. 5.* |
| 7. „ <i>astraciformis</i> . | 12. <i>Favia clouei</i> . |

* This species could not be satisfactorily determined, and is so labelled in the collection deposited in the British Museum.



KEY.



Montipora ramosa.



Dead *Montipora ramosa*.



Porites (massive).



Pocillopora.



Symphyllia.



Lobophyllia.



Fungia.



Halomitra.



Galaxea.



Sinularia flexibilis.



Sarcophytum trocheliophorum.



Lobophytum crassum.



Sinularia sp.



Sinularia polydactyla.



Alcyonium pachyclados.



Lobophytum sp.



Rock and sand (black).

1 2 3 4 5 6 feet.

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DESCRIPTION OF PLATE XIV.

Large-scale map of an area on the REEF CREST of Yonge Reef, one of the Outer Barrier Reefs. (For position of the various regions of Yonge Reef see Vol. III, No. 2, Text-fig. 5, and Plate XVII, fig. 2.) Scale 1/18.

The area is dry at low tide, and shows a limited amount of coral growth on a smooth and level substratum of coral rock covered with a veneer of pink nullipores (black ruled with white). Two starfish, *Linkia guildingii*, lie on the rock. For further description of the area see p. 304.

Key to species indicated by numbers on the map :

- | <i>Favia</i> , etc. | <i>Acropora</i> . |
|--------------------------------------|----------------------------|
| 1. <i>Goniastrea retiformis</i> . | 4. <i>Acropora hebes</i> . |
| 3. <i>Favia abdita</i> . | 5. „ <i>quelchi</i> . |
| 9. <i>Coeloria</i> sp. | 6. „ <i>gemmifera</i> . |
| 10. <i>Goniastrea</i> K. 5.* | 7. „ <i>hyacinthus</i> . |
| 11. <i>Leptastrea ehrenbergana</i> . | 9. „ <i>pulchra</i> . |
| 12. <i>Favia clouei</i> . | 10. „ <i>rosaria</i> . |
| 13. „ <i>laxa</i> . | 11. „ <i>decipiens</i> . |
| 14. „ <i>wakayana</i> . | |

* This species could not be satisfactorily determined, and is so labelled in the collection deposited in the British Museum.



KEY.

-  *Favia*, etc. (central number indicates species; see legend).
-  Massive *Porites*.
-  Encrusting *Montipora*.
-  Grey *Zoanthid*.
-  Smooth rock covered by nullipores.
-  Rock at a lower level
-  *Tubipora*.
-  Dead coral.
-  *Millepora*.
-  *Pocillopora verrucosa*.
-  *Acropora* (number and conventions indicate species: see legend).
-  *Acropora decipiens*.
-  *Hydnophora*.
-  Sponge, *Phyllospongia ridleyi*.
-  Green alga, *Chlorodesmis comosa*.

DESCRIPTION OF PLATE XV.

Large-scale maps of two areas in the OUTER MOAT of Yonge Reef, one of the Outer Barrier Reefs. (For position of the various regions of Yonge Reef see Vol. III, No. 2, Text-fig. 5, and Plate XVII, fig. 2.) Scale 1/18.

The rocky substratum, hard and smooth and covered with a veneer of nullipores, is not so level as on the Reef Crest. The left half of the upper area, and the top half of the lower area, lie at a lower level than the rest of these areas, and are covered with about 1 foot of water. The remaining rock is higher, and projects out of the water in places. Corals are luxuriant and soft Alcyonaria few. For further description of these areas see p. 305.

Key to species indicated by numbers on the map :

<i>Favia</i> , etc.	<i>Acropora</i> .
8. <i>Favia halicora</i> .	5. <i>Acropora quclchi</i> .
10. <i>Goniastrea</i> K. 5.*	6. „ <i>gemmifera</i> .
11. <i>Leptastrea ehrenbergiana</i> .	12. „ <i>hyacinthus</i> .
14. <i>Favia wakayana</i> .	13. „ <i>delicatula</i> .
	„ <i>decipiens</i> (separate convention).

* This species could not be satisfactorily determined, and is so labelled in the collection deposited in the British Museum.



KEY.

-  *Favia*, etc. (central number indicates species; see legend).
-  Massive *Porites*.
-  Encrusting *Montipora*.
-  *Acropora palifera*.
-  *Pocillopora verrucosa*.
-  *Pocillopora eydouxi*.
-  Encrusting *Millepora*.
-  *Hydnophora*.
-  *Platygyra*.
-  *Coeloria*.
-  *Acropora hyacinthus*, etc.
-  *Acropora decipiens*.
-  *Acroporus* (central number indicates species; see legend).
-  Branching *Millepora*.
-  Higher levels } Rock covered by nullipores.
Lower levels }
-  *Phyllospongia ridleyi*.
-  *Aglaophenia cupressina*.
-  *Nephthya mollis*.
-  *Paralemnalia thyrsoidea*.

1 2 3 4 5 6 7 feet.

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DESCRIPTION OF PLATE XVI.

Large-scale maps of areas on the INNER PARTS of Yonge Reef, one of the Outer Barrier Reefs. (For position of the various regions of Yonge Reef see Vol. III, No. 2, Text-fig. 5, and Plate XVII, fig. 2.) Scale 1/18.

The upper area lies in the ANCHORAGE CORAL ZONE. Pools of water (black) about 4 feet deep over sand lie among irregular masses of coral rock (stippled grey). The rock is not so strongly incrustated with nullipores as in the preceding areas, and it bears a rich and varied coral fauna. Fish abound in the pools. For further description see p. 306.

The lower area lies at the edge of a CORAL HEAD in the Zone of Coral Heads lying leeward of the Anchorage Coral Zone. This area differs from the last in that the water lies at a depth of 4-5 fathoms, so that large stag-horn-like growths of acropores can find place in the open water, and the tops of the coral rock masses are richly covered by corals, particularly conspicuous being the dish-shaped *Acropora hyacinthus*, etc., and the coarse form of *Acropora gemmifera*. Compare also with the Low Isles coral head on Plate XII.

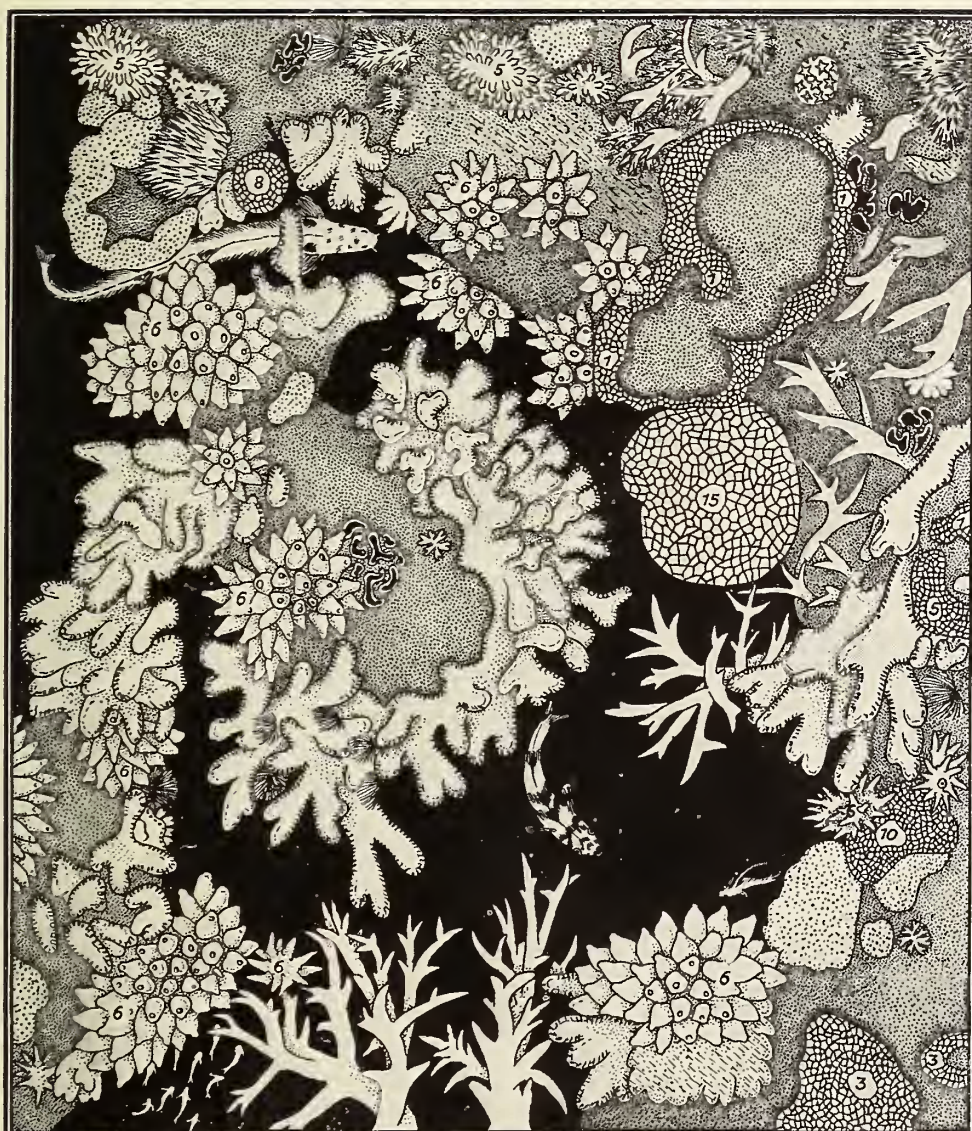
Key to species indicated by numbers on the map :

<i>Favia</i> , etc.	<i>Acropora</i> .
1. <i>Goniastrea retiformis</i> .	5. <i>Acropora quelchi</i> .
3. <i>Favia abdita</i> .	6. „ <i>gemmifera</i> , stout and fine varieties.
5. „ <i>favus</i> .	12. „ <i>hyacinthus</i> , etc.
8. „ <i>halicora</i> .	„ <i>palifera</i> (separate convention).
10. <i>Goniastrea K. 5</i> .*	„ spp. large stag-horn growths (separate convention).
15. <i>Favia vasta</i> .	
X. Unidentified, but occurs on Low Isles coral heads also.	

* This species could not be satisfactorily determined, and is so labelled in the collection deposited in the British Museum.

KEY.

-  *Favia*, etc. (central number indicates species; see legend).
-  Massive *Porites*.
-  *Goniopora*.
-  *Galaxea*.
-  *Stylophora*.
-  *Pocillopora verrucosa*.
-  *Pocillopora danae*.
-  *Pocillopora bulbosa*.
-  *Millepora*.
-  *Seriatopora*.
-  *Fungia*.
-  *Acropora quelchi*.
-  *Acropora palifera*.
-  *Acropora hyacinthus*.
-  *Acropora gemmifera*, stout and slender growth forms.
-  Large "stag-horn" *Acroporas*.
-  Rock.
-  Sand covered by several feet of water.
-  Dead corals.
-  Green alga, *Chlorodesmis comosa*.



1 2 3 4 5 6 7 feet.